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THE RATE OF RECESSION OF NIAGARA FALLS.

By G. K. Gilbert.

INTRODUCTION.

The erosive work of the cataract of Niagara is exceptionally rapid. This depends primarily on the great power of the falling water, but in part on the character of the local geologic structure. The rocks are stratified and lie nearly level. The upper layers are of limestone, strong and resistant; the lower, consisting chiefly of shale, are comparatively weak and yielding. As the shales are worn away below, the limestone beds are undermined, so that their edges project like a cornice and are deprived of support. From time to time they yield to the force of their own weight and fall away in large blocks. Each rock fall causes a jar of the ground which is perceived by people in the vicinity, and results in a modification of the crest of the cataract which is readily seen by anyone familiar with its outline. Such changes of the crest have been observed from time to time ever since the neighboring banks of the river were occupied by white men. It is highly probable that they were also observed by Indians before the advent of white men, but on this point I have made no inquiries, as Indian traditions are not likely to be sufficiently definite to aid in determining the rate of progressive change in the position of the cataract.

The surface of Lake Erie is 325 feet higher than the surface of Lake Ontario. The belt of land between them includes two plains, of which the higher and broader is raised but little above the level of Lake Erie, and the lower slopes gently to the shore of Lake Ontario. The descent from the upper to the lower is abrupt, constituting a line of cliffs parallel to the shore of Ontario and known as the Niagara escarpment. The river, issuing from Lake Erie at Buffalo, flows at first on the upper plain. It is there broad and comparatively shallow and has no valley. At the falls it suddenly drops into the head of a narrow gorge which is 6 miles long and extends to the escarpment. Within the gorge it is narrow and contained by steep walls. Near the head of the gorge the water is deep, the current moderate, and the descent small, but farther on are fierce rapids with steep descent. Some of these relations are shown in Fig. 2. As the falls are at the head of the gorge, it is evident that their recession makes the gorge longer.

Among the early observers of the falls was Robert McCauslin, who remained there from 1774 to 1783. After describing the escarpment at Queenston he says:

"It is universally believed that the cataract was originally at this ridge, and that it has by degrees worn away and broke down the rock for the space of these six or seven miles. Some have supposed that from these appearances, conjectures might be formed of the age of this part of the world. To enter upon such a calculation, it would previously be necessary to ascertain how much the fall had retired in a hundred years, or any other certain period. Suppose that we were even in possession of such a fact, still the conclusions drawn from it would be liable to the greatest uncertainty, as it is evident that the space of rock broke down and worn away in a certain number of years would not always be the same. The more or less hardness and brittleness of the rock in different parts; the greater or less severity of the frosts in different years, and the quantities of water that flowed at different periods in the cataract of the river, would all occasion considerable variations. This retrocession of the Falls does not by any means go on so quickly as some have imagined. During nine years that I have remained at Niagara, very few pieces of the rock have fallen down which were large enough to make any sensible alteration in the brink; and in the space of two years I could not perceive, by a pretty accurate measurement, that the northeast brink had in the least receded. If we adopt the opinion of the Falls having retired six miles, and if we suppose the world to be 5,700 years old, this will give about sixty-six inches and a half for a year, or sixteen yards and two-thirds for nine years, which I can venture to say has not been the case since 1774."

Enys, who visited the cataract in 1787, quotes the opinion of residents that "the Falls have altered their position or retreated since the memory of men," but dissents from the view (which seems also to be generally entertained) that the original situation of the falls was at Queenston. Weld, whose visit to the falls was in 1796, says that "even within the memory of

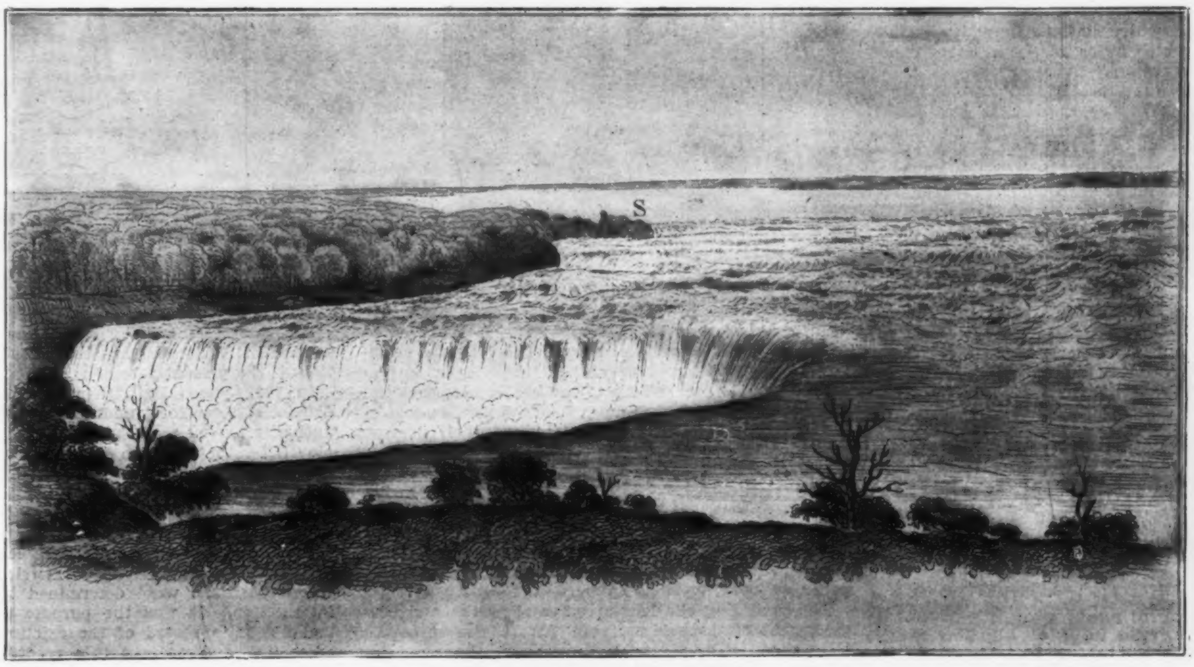

FIG. 7.—HORSESHOE FALL IN 1827.

Copy of sketch by Capt. Basil Hall, made with camera lucida, from veranda of Forsyth's Hotel.

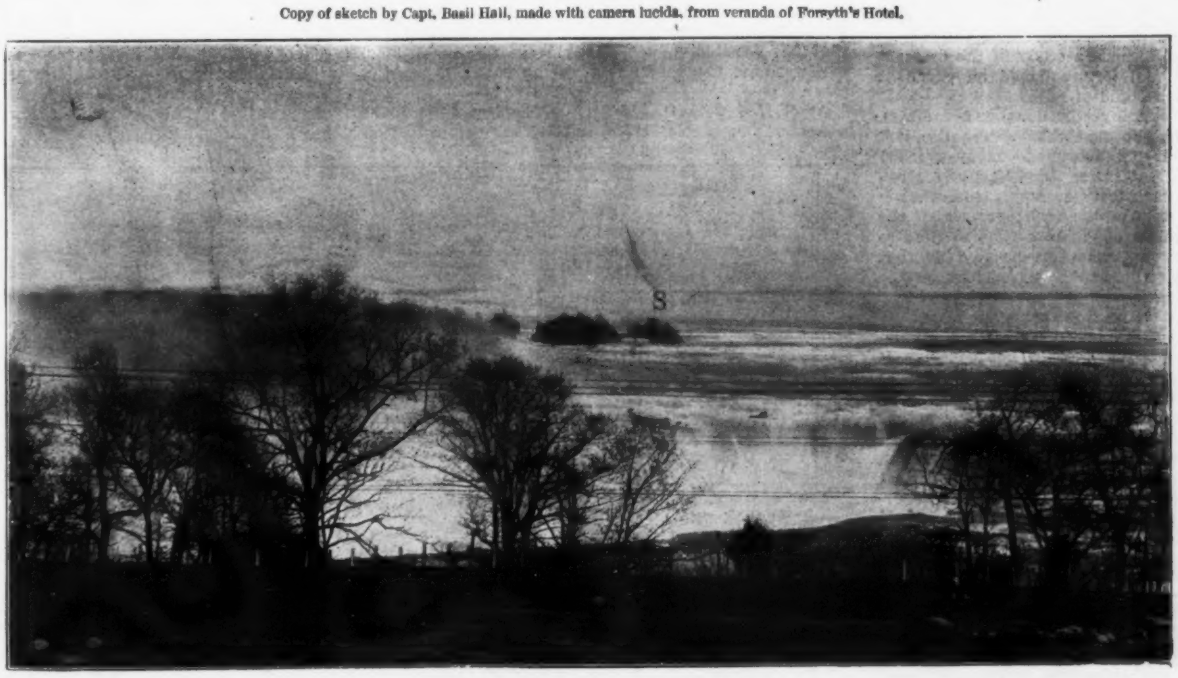

FIG. 8.—HORSESHOE FALL IN 1895.

Photograph from same point as sketch, Fig. 7. The island at S is common to the two views. Their comparison shows the recession of the fall and the change in its outline.

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many of the present inhabitants of the country, the falls have receded several yards." He favors the theory that the gorge from Lewiston to the falls was made by the falls, and his discussion of the subject shows him to have been a close observer and clear thinker.

Volney two years later repeats the general statement of observed recession, and adds:

"If the European colonists or travelers, to whom this region has been accessible for a century and a half, had made careful memorandums, from time to time, of the state of the fall, we should, by this time, have been able to trace the progress of those revolutions, which are easily proved to have taken place, by vestiges and indications which present themselves at every step."

And still further, in a footnote:

"It is extremely desirable that the government of the United States, at present under the direction of a friend to the arts and sciences (Jefferson), should order to be drawn up an exact description of the present state of the cataract. This statement, compared with subsequent appearances, observed from time to time, would enable us to trace with certainty the changes that may hereafter take place."

Francis Hall, 1816, says:

"The name of 'the Horse shoe,' hitherto given to the larger Fall, is no longer applicable: it has become an acute angle. . . . An officer who had been stationed in the neighborhood thirty years, pointed out to me the alteration which had taken place in the center of the Fall, which he estimated at about eighteen feet in the thirty years."

Gilpin, whose visit was probably a few years later, says:

"The toe of the shoe, however, is now an angle, rather than a curve; but the inhabitants and early visitors affirm that it was formerly more round, and has gradually assumed its present angular form, within their recollection. . . . Mr. Forsyth, who has resided upon the spot for more than forty years, says, that within his recollection, the center of this fall has receded from ten to fifteen yards; and, as some intelligent travelers have placed upright a few large stones in front of the hotel, which, when taken in a line, point exactly to that spot, it will of course be ascertained, at the end of a certain number of years, how much this center recedes annually."

Schoolcraft, whose visit was in 1820, describes the

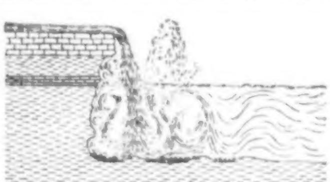

FIG 1.—DIAGRAMMATIC PROFILE OF HORSESHOE FALL, ILLUSTRATING MODE OF EROSION AND RECESSION.

undermining of the limestone by the fretting away of the shale, and mentions with approval the theory that the falls were anciently at Lewiston.

Capt. Basil Hall, R.M., made a study of the cataract in 1827, and two years later published an excellent description, from which I quote:

"In the course of our investigations and rambles, we met a gentleman who had resided for the last thirty-six years in this neighborhood—happy mortal! He told us that the Great Horse Shoe Fall had, within his memory, gone back forty or fifty yards—that is to say, the edge, or arch of the rock over which the water poured, had broken down from time to time to that extent. This account was corroborated by that of another gentleman, who had been resident on the spot for forty years.

"As these statements came from persons of good authority, I was led to examine the geological circumstances more minutely; for I could not conceive it possible, that the mere wearing of the water could perform such rapid changes upon hard limestone. The explanation is very simple, however, when the nature of the different strata is attended to. In the first place, they are laid exactly horizontal, the top stratum being a compact calcareous rock. In the next place, I observed, that in proportion as the examination is carried downward, the strata are found to be less and less indurated, till, at the distance of a hundred feet from the topmost stratum, the rock turns to a sort of loose shale, which crumbles to pieces under the touch; and is rapidly worn away by the action of the violent blasts of wind, rising out of the pool into which this enormous cascade is projected.

"In process of time, as the lower strata are fairly eaten or worn away, the upper part of the rock must be left without a foundation. But owing to the tough nature of the upper strata, they continue to project a long way over before they break down. There must come periods, however, every now and then, when the overhanging rock, with such an immense load of water on its shoulders, will give way, and the crest, or edge, of the Fall will recede a certain distance. At the time of our visit, the top of the rock, or that over which the river was directed, overhung the base, according to the rough estimate I made, between 35 and 40 feet, thus forming a hollow space, or cave, between the falling water and the face of the rock.

"While the above lines were actually in the printer's hands, my eye was accidentally caught by the following paragraph in a newspaper:

"'Niagara Falls.—A letter from a gentleman at that place, dated December 30, 1828, states, that on the Sunday evening preceding, about 9 o'clock, two or three successive shocks or concussions were felt, the second of which was accompanied by an unusual rushing sound of the waters. The next morning it was discovered, that a large portion of the rock in the bed of the river, at the distance of about two-fifths from the Canada shore to the extreme angle of the Horse Shoe, had broken off, and fallen into the abyss below. The whole aspect of the Falls is said to be much

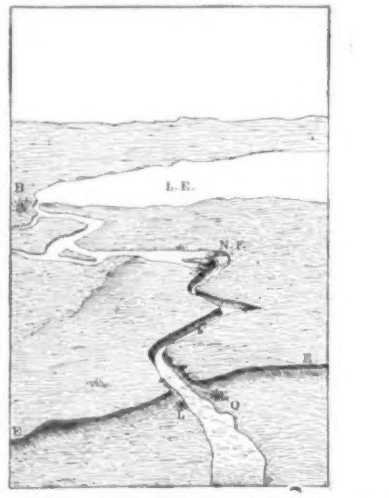

FIG. 2.—BIRD'S EYE VIEW OF NIAGARA RIVER.

The view is southward, or upstream, from a point above the shore of Lake Ontario, and shows the two plains, the escarpment, and the gorge. B, Buffalo; N. F., Niagara Falls; L., Lewiston; Q, Queenston; E, E. Niagara escarpment.

changed by this convulsion. A course of high winds for several days previous to its occurrence, producing an accumulation of water in the river, is supposed to have been the immediate cause. This gradual crumbling away of the rock over which the Niagara is precipitated, adds plausibility to the conjecture, that the Falls were once as low down as Lewiston, and have for centuries been traveling up toward their present position.'"

Capt. Hall also published a series of sketches of the falls, and as these were made with the camera lucida they have exceptional value. They, in fact, constitute the first record bearing on the rate of recession from which measurements can profitably be made, and there is frequent reference to them in other parts of this paper.

The preceding citations serve to show the early development of three ideas: (1) That the crest of the Horseshoe Fall is receding upstream, the recession being caused by the energy of the cataract; (2) that the gorge below the falls was created by this process of recession, the position of the falls having originally been where the mouth of the gorge now is; and (3) that it is possible, by sufficiently accurate observations, to determine the rate at which the change is taking place.

Associated with the idea of measuring the rate of recession was that of applying it to the determination

care. As developed by careful study, the problem proved to be complex and difficult. It came to be recognized not only that the rate of recession in different parts of the gorge must have varied with the height of the cataract, the temporary width of the stream, and the thickness of the capping limestone, which is different in different places, but also in a very important way with the volume of water carried by the river, which has been subject to extreme fluctuations. The influence of these various conditions assumed prominence in the discussion, and although the rate of present recession came to be fairly well known, opinions still differed widely as to the total period

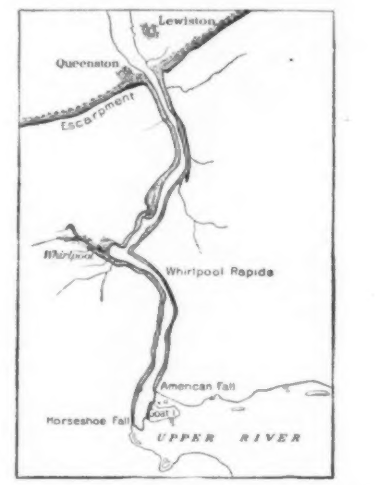

FIG. 3.—MAP OF THE NIAGARA GORGE, SHOWING ITS RELATION TO THE FALLS AND THE ESCARPMENT.

represented by the gorge. The age of the gorge is outside the scope of the present paper, and the subject is here mentioned only to show the basis of the strong interest which has been felt in the determination of the present rate of recession.

In 1841 James Hall, then geologist of the fourth district of New York, undertook the preparation of an authoritative map of the crest of the falls, and employed for that purpose E. L. Blackwell, a civil engineer. The work was completed in the autumn of 1842, at which time a series of monuments was established at the principal trigonometric points. The map was published the following year, together with descriptions of the monuments and a table of compass bearings from the various trigonometric points to objects whose positions were determined by the method of intersection. It was the purpose of this survey to make definite record of the existing position of the crest line and connect this record with permanent monuments, so that by means of a similar survey at some future time the extent of changes might be determined. This purpose it has served. Monuments then placed have been used as starting points in subsequent surveys, and two of them are still extant.

As this work by our great master in geology marks a turning point in the subject—the change from the vague to the definite—I quote a few passages to show his point of view:

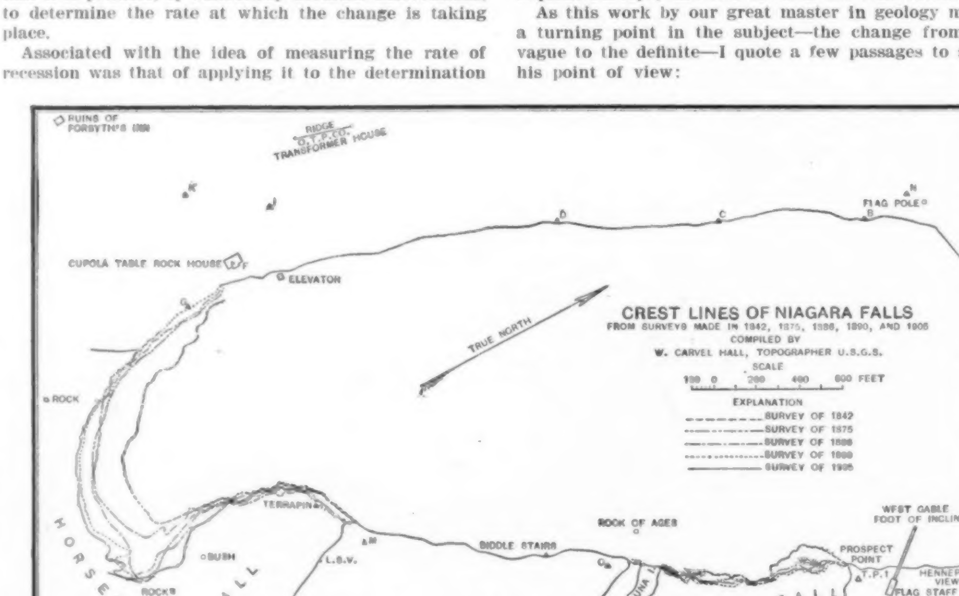

FIG. 4.—THE PRESENT CREST LINE OF NIAGARA FALLS WITH FORMER CREST LINES SINCE 1842.

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of the time consumed by the river in the making of the gorge. By some of the earlier writers the age of the gorge was obscurely connected with the age of the world as estimated from Biblical data; by others it was recognized as a small fraction of geologic time. With the progress of knowledge of the local geologic history there was increasing interest in the time estimates for the river, and the various conditions affecting the estimate came to be scrutinized with much

"Among the phenomena of waterfalls and river gorges, the cataract of Niagara is justly regarded as holding the first rank, and as standing an index in the path of time, by which the influence of numberless ages upon the surface of our planet may be recorded. Its present, its former, and its prospective conditions have engaged the investigation and speculation of many philosophers. The possible consequences of its entire reduction, and the drainage of

the upper lakes, have excited the wonder and the apprehensions of many. The estimated time of its recession has sprinkled gray hairs among the fresh locks of the young and blooming earth, and alarmed those who would consider her still youthful in years.

"But amid all these speculations, Niagara still remains; the thunder of its cataract still reverberates through its deep chasms, and its ocean of waters still rolls on as, unknown to the white man, it rolled a thousand years ago. When we come to the investigation of facts, we find that, except to travelers and the aborigines, Niagara was unknown until within the last fifty years; and that even during this time no accurate observations have been made, no monument erected to determine whether the falls are retrograding or not. The testimony of living witnesses and historical evidence unite in confirming the opinion that the water is wearing away the rock, and that the outline of the falls has changed. From these general observations, it has been estimated that they have receded at the rate of about forty feet in fifty years. Without pretending to question the accuracy of this or any other estimate of the kind, or to establish any rate of retrogression in the falls, we may examine its present, and from numerous facts infer its past condition; and from these we are entitled to draw an inference for the future, though without specifying time."

The foresight with which he planned the survey and record for the specific purpose is shown by the statement with which the map is introduced:

"The accompanying map has been constructed from a very careful survey by Mr. Blackwell, giving the present position and outline of both falls, and the river banks upon either side. Upon application to His Excellency Sir Charles Bagot, late Governor-General of Canada, I was authorized to establish monuments upon the Canada shore, and was also kindly offered every other aid to promote the objects of the survey. These monuments, together with those in New York, will enable future observers to ascertain the amount of recession during any given period. In places where the rock is exposed, copper bolts have been fixed, and in other places hewn stone monuments. The starting point for all these observations is a copper bolt fixed in the rock on the north side, near the edge of the American fall."

In 1875 the second survey of the crest line was made by the United States Lake Survey under the direction of Major C. B. Comstock, the field work being by F. M. Towar. The United States Geological Survey undertook the third survey, which was made by Robert S. Woodward in 1886. The fourth survey was made in 1890, by A. S. Kibbe, under the direction of John Bogart, State engineer of New York, and a very full report was published. In this report the maps of the three preceding surveys are republished, and the crest lines given by those surveys are also placed on the new map. The fifth survey was made in the spring of 1905, by the United States Geological Survey and the State engineer of New York, the work being done by W. Carvel Hall.

The crest lines determined by the five successive surveys are platted together in Fig. 4, and their examination demonstrates clearly the gradual retreat of the crest of the Horseshoe Fall. Each mapped crest line is, on the whole, farther upstream than its predecessor, and their interspaces are roughly comparable with the time intervals between the making of the surveys; but each of these statements requires qualification. The region of maximum retreat has shifted from one part to another of the crest during the period of observation, so that in any one part the rate of retreat has been irregular; and when the chart is closely scrutinized it is found that the different lines overlap one another at various points, so that if all of them were rigidly accurate their record would show that the crest line had in places advanced downstream, instead of retreating. In the report of the last survey it is suggested that some of these discrepancies may be explained by an actual sliding forward of upper layers of limestone before they toppled over the brink, but the greater discrepancies can not be explained in this way, and the discrepancies as a whole are unquestionably due to errors in the topographic work, chiefly through failure to identify points previously sighted when intersecting bearings were taken. Fortunately, they are not of such character or extent as to impair the general conclusions to be drawn from the work; but they serve to caution the student against any overrefinement in the discussion of results.

In recent years the diversion of water from the falls for electric power and for canal purposes has rapidly increased, and existing charters authorize so large a draft upon the river that it has come to be recognized that the scenic value of the cataract is in peril. A vigorous protest has been made by lovers of natural beauty, and negotiations are in progress for an international agreement to check and regulate the economic exploitation of the river. Whatever the outcome of these negotiations, there is no reason to expect that the natural flow of the river will be restored, and it is believed that from this time onward the natural conditions will be so far interfered with as to modify the rate of recession. As the geologist is primarily interested in the natural rate of recession, the present time is opportune for a summing up of the data. In fact, the survey of 1905 was ordered in view of the change of conditions from natural to artificial.*

FIG. 9.—EASTERN PART OF HORSESHOE FALL ABOUT 1885.

Shows talus of limestone blocks. At the left, near Goat Island, there was a large rock fall in 1852.

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The Horseshoe Fall is at the head of the gorge. From its edges the walls of the gorge run northeastward approximately parallel. The American Fall is at the side of the gorge, 2,500 feet from its head, and is separated from the Horseshoe Fall by Goat Island. A few hundred years ago the two falls were together, the position of the united cataract being somewhere in the neighborhood of the present American Fall. The subsequent retreat of the Horseshoe Fall has had the effect of lengthening the gorge, but the American Fall has not in the same time made an alcove in the side of the gorge. With reference therefore to the question of the age of the gorge, it is the Horseshoe Fall whose rate of recession is important.

The chief data for the estimation of the rate of recession are the maps of 1842 and 1905, the time interval being sixty-three years. The outlines from those maps are shown in Fig. 6. These data, like other statistical data, can be discussed in a variety of ways and made to yield widely divergent results—a fact sufficiently illustrated by earlier estimates of the rate of recession based on comparisons of the map of 1842 with that of 1875, 1886, or 1890. The following paragraphs therefore set forth somewhat fully the method here used, with the principal considerations on which they are based.

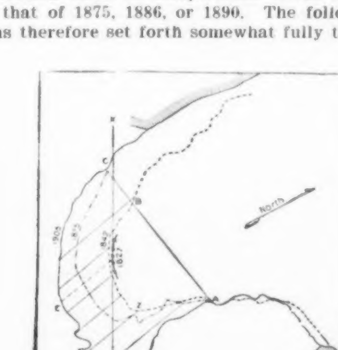

FIG. 6.—OUTLINES OF HORSESHOE FALL IN 1842, 1875 AND 1905, WITH LINES USED IN COMPUTING THE RATE OF RECESSION. THE LINE OF CROSSES SUGGESTS A POSITION OF PART OF THE CREST IN 1827.

In the lengthening of the gorge the river does its principal work in that part of the Horseshoe curve where the current is deepest. The agitation of the plunging water is there so powerful as to roll about the fallen blocks of limestone, using them as tools to grind the shale, and at the same time breaking them up and eventually washing them downstream. The scour maintains a deep hollow beneath this part of the fall, a hollow whose depth is greater than the height of the fall. (Fig. 1). At the sides of the channel, especially near the right bank, where the sheet of falling water is comparatively thin, the fallen blocks

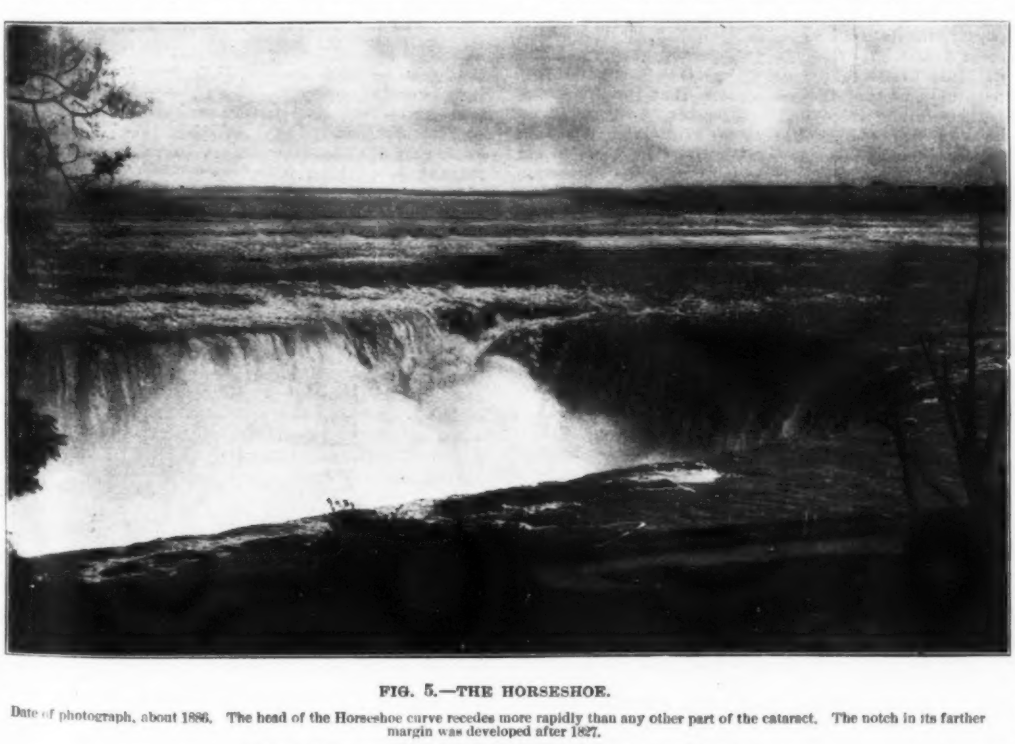

FIG. 5.—THE HORSESHOE.

Date of photograph, about 1886. The head of the Horseshoe curve recedes more rapidly than any other part of the cataract. The notch in its farther margin was developed after 1827.

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* Since this paper was written it has come to my knowledge that a resurvey of the Niagara River is being made by the United States Lake Survey, the field work for the crest of the falls having been done in the summer of 1906. This will afford an additional datum on the rate of recession, but is not likely to affect the computation to a material extent. The addition of one year to the period of observation will probably be offset by changes occurring within that year. Inspecting the Horseshoe curve in August, 1906, I was confident that a salient near the angle of the curve, which was recorded by the surveys of 1890 and 1905, did not then exist.—G. K. G.

are not cleared away, but cumber the base of the cliff. (Fig. 9.) As the cataract retreats it leaves behind it a deep channel, or elongated pool, in which the current is slow. Below the cataract the gorge is widened at the top by the falling away of its banks. When the shale is exposed to the air it becomes subject to frost action, and for a time the limestone ledge above continues to be undermined, but a practical limit is reached as soon as the talus of fallen material covers the slopes of shale, and thereafter the change is exceedingly slow. The real lengthening of the gorge is along that portion of the Horseshoe where the sheet of falling water is heavy enough to clear away the débris and maintain a deep pool. The retreat of the cliff on either side of this portion is secondary, and appears to have little or no bearing on the question of the rate at which the gorge is growing longer. I have therefore restricted attention to the central part of the Horseshoe curve.

As the two crest lines compared are irregular in outline, a certain confusion arises if the recession of different parts is considered separately. At one place the recession seems to have one direction, at another place to have another direction, and various complications ensue when attempt is made to combine measurements made in different directions. In view of this difficulty it has appeared to me both convenient and legitimate to assume some one direction as the general direction of recession and at all points measure the amount of recession on lines parallel to that direction. From an inspection of the crest lines as wholes and in their relation to each other I have inferred such a general direction of recession, and assuming it to apply to the entire central tract of the Horseshoe, have drawn the system of parallel lines seen in Fig. 6. There are six of these lines, each extending from the crest line of 1842 to that of 1905. Their interspaces, according to the scale of the map, are 100 feet wide. The average length of these lines represents approximately the average recession of the cataract in the part where the sheet of falling water is heaviest. Their lengths are, severally, 430, 292, 260, 276, 317, and 412 feet, giving an average length of 331 feet. This distance divided by the number of years, 63, gives as the average annual recession 5.3 feet.

A somewhat allied method of estimate is concerned with areas. Still restricting attention to the central portion of the Horseshoe curve, I have drawn a line from *A*, the point at which the two crest lines begin to diverge, to the opposite shore at *C*, making its direction lie at right angles to the general direction of recession. The area contained between the two crest lines *AZB* and *AEC*, and limited downstream by the straight line *AC*, may be regarded as the area removed by the central portion of the fall between 1842 and 1905. The corresponding width of this part of the gorge in 1842 was *AB*, 570 feet; in 1905 *AC*, 760 feet. The mean of these, 665 feet, is assumed as the average width for the intervening period. The indicated area between the crest lines was found by measurement to be 223,000 square feet, and this quantity being divided by 665 feet, gives 335 feet as the average recession in a direction at right angles to *AC*. Dividing, as before, by 63, the number of years, I obtain again as an estimate of the average annual rate 5.3 feet.

The close coincidence of these two results is accidental, although a general agreement was to be expected because the assumptions underlying the computations are harmonious. As already stated, materially different results may be obtained with different assumptions.

Less harmonious results are obtained if the period from 1842 to 1905 is divided into parts and the parts are separately computed. Their discordance has two sources which can not be fully discriminated. From the nature of the case the rate of recession is not uniform. The distance to which the cornice of limestone comes to project before it is broken away depends not only on the strength of the rock, but on the local arrangement of vertical joints by which it is traversed and also to some extent on the shape of the temporary outline of the crest. The fall of rock is therefore irregular and only obscurely rhythmic. In a period measured by centuries these irregularities would have little influence on the general average, but for short periods their influence may be great. A second source of discrepancy in the results lies in the inaccuracy of the surveys. Even where the sheet of water is so thin that the rock is visible through it, there is some liability to error, and where the topographer could see only the curved and changing surface of the rushing water his observations were necessarily somewhat indefinite. Two observers might in fact differ by several feet in their estimate of the actual position of the rock crest over which the water pours. The only results for shorter periods which it seems advantageous to place on record are those which use the map of 1875 in connection with the maps of 1842 and 1905. This approximately halves the whole period of sixty-three years, the earlier part being thirty-three years in length and the later part thirty years. By applying to these two divisions the methods already described for the whole period, and employing the same ordinates and the same limiting line, the results given in the table were obtained.

The indication is that during the thirty years following 1875 the lengthening of the gorge went on at a somewhat faster rate than during a similar period preceding that date. While it is quite possible that the apparent variation in the rate is sufficiently accounted for by the irregularity of the breaking away of the limestone sill, it is also possible that the rate has been influenced by a special condition affecting the mode of recession. A change in the outline of the fall which was mentioned nearly a century ago as diminishing its resemblance to a horseshoe consisted in the development of an angle near the head of the curve and on the side toward Goat Island (*Z*, Fig. 6). Within the last thirty years the recession has been especially rapid in that angle, and there has developed a deep recess or notch. This appears to have been occasioned by a local weakness of the limestone, presumably its subdivision by a belt of vertical joints. Within the notch the mode of recession has been so far modified that the upper layers of limestone have been removed before the lower, so that at certain stages of the process the water after falling from the crest has been caught by a shelf. The configuration can be better understood by an examination of Fig. 5, which is based on a photograph made in or near the year 1886. Whatever the method of erosion in the notch, it appears to be superadded to the general erosion by undermining, and an acceleration of the rate may plausibly be ascribed to it.

RATES OF RECESSION COMPUTED FOR VARIOUS PERIODS AND BY DIFFERENT METHODS.

Limiting dates.	Length of period.	Average annual recession.	
		Computed by parallel ordinates.	Computed by areas.
	Years.	Feet.	Feet.
1842-1875	33	4.0	4.4
1875-1905	30	6.6	5.6
1842-1905	63	5.3	5.3

If we regard the general method of recession by the process of sapping or undermining as normal, and the influence of joint systems as exceptional and temporary, the rate of recession computed for the period from 1842 to 1875 should be accepted as normal and the best available for use in geologic computations; but this involves the assumption that the limestone ledge was not affected in other parts of the gorge by belts of weakness similar to the one which has been exposed during the last few decades. It seems to me better, on the whole, to assume that the limestone eroded between 1842 and 1905 is fairly representative, so far as strength is concerned, of all that portion of the limestone ledge in which the cataract has done its work.

The maps of 1842 and 1905 represent the earliest and latest surveys, but do not include quite all the data worthy of consideration in this connection. The sketch by Basil Hall, made with the aid of a camera lucida, in 1827, has a claim for accuracy by no means to be disregarded. In the use of the camera lucida the draftsman sees the landscape as though faintly pictured on a sheet of paper, and at the same time sees the pencil with which he traces its outlines. Before photography this method was the most accurate known for recording the outlines of a landscape, and in skillful hands it gives results of notable precision. There is much internal evidence that Capt. Hall's sketches at Niagara were made with care and fidelity, and in view of these facts I have thought it worth while to endeavor to combine his record with the records by mapping. He tells us that his principal sketch of the Horseshoe Fall (Fig. 7) was made from the upper veranda of Forsyth's Inn, on the Canadian shore, and the relation of the veranda to the inn is shown by a contemporary drawing by Mrs. Trollope. The inn itself long since disappeared, but its position is still marked by the ruins of its foundations. Through the courtesy of Mr. James Wilson, superintendent of Victoria Park, who caused the necessary scaffolding to be constructed, I was enabled, in 1895, to place a photographic camera within a few feet of the position once occupied by the camera lucida, and this position has also been located on the map of 1905 (Fig. 4). A comparison of the two pictures made from that position yielded the identification of a common point on one of the Three Sister Islands (Fig. 7), and with the aid of the orientation thus secured it became possible to draw upon the modern map the line *XY* in Fig. 6, representing a direction from Capt. Hall's point of view tangent to the head of the Horseshoe Fall. It will be observed that this line passes very near to the head of the curve as drawn in the map of 1842, the implication being that at the head of the gorge very little recession had occurred in the fifteen years intervening between 1827 and 1842. I am not sure that this single line, obtained by so circuitous a method, should be allowed to influence the result based on two topographic surveys, but to whatever extent it is given consideration its tendency is to reduce the estimate of the annual rate.

(To be continued.)

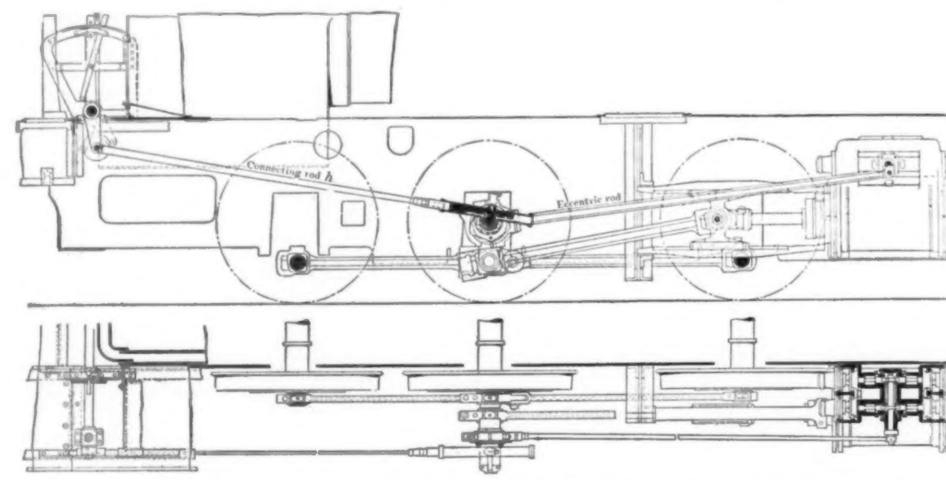

Fig. 1.—GENERAL ARRANGEMENT OF THE LENTZ REVERSING MECHANISM.

THE LENTZ REVERSING MECHANISM.

A few months ago the Zeitschrift des Vereines Deutscher Ingenieure described the simple but ingenious Lentz reversing mechanism. Fig. 1 shows the general arrangement of the design, and in Fig. 2 a section of the detail which is particularly novel is given.

A seen from the cut, the crankpin is provided with an outside extension which carries a stud *f*. On this stud the eccentric *a* is mounted, and is free to move around the stud as a center. A bushing *b* is movable along the stud *c*, which is located in line with the wheel axle. This bushing is keyed to the stud by means of the key *d*, and will thus rotate with the wheels. The bushing is provided with spiral teeth on the outside, which mesh with teeth in the eccentric *a*. It is evident that a longitudinal movement of the bushing *b* will move the eccentric around the stud *f*. On the outside of the bushing *b* there is a second bushing *e* which is keyed to the final cover *k*, and is stationary

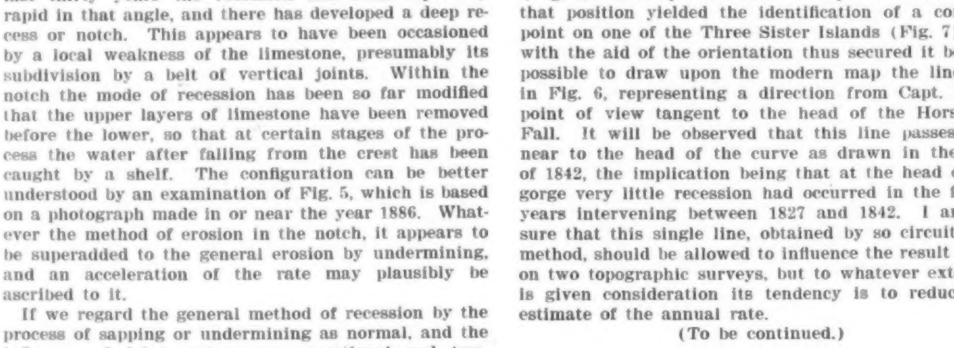

Fig. 2.—SECTION AND SIDE VIEW OF THE LENTZ REVERSING MECHANISM.

in regard to the rotary motion of the bushing *b*, but moves with this latter bushing in a longitudinal direction by means of four flanges, *g*, on the outside surface.

This second bushing is in its turn provided with spiral teeth on the outside, which mesh with teeth in the rod *h* connected with the regular reversing lever. It is now evident that a motion of the rod *h* in its longitudinal direction will cause the bushing *c*, and at the same time the bushing *b*, to move. The movement of the latter bushing, however, turns the eccentric around its support, and places it in any desired position. The valves themselves are operated by a horizontal shaft, turned by a small crank connected with the eccentric rod. The advantages claimed for this design are the comparatively small number of parts, and the possibility of making the mechanism perfectly dustproof. This construction has been practically tried in Germany in at least two instances, and proven to work entirely satisfactory. It is known as the Lentz reversing mechanism.—Machinery.

THE SPECIFIC HEAT OF SUPERHEATED STEAM.

THE National Physical Laboratory experiments on the specific heat of superheated steam have steadily proceeded during the year, and several improvements have been made in the apparatus used. It was found that though the mica lagging originally fitted to the superheater was efficient in reducing the loss of heat by radiation, yet its capacity for heat was so great as to cause other errors to arise. Very careful observations showed that if any change of temperature occurred in the steam in the superheater, the lagging either supplied or absorbed heat for a very considerable time before a new steady condition was obtained. It was, of course, impossible to prevent small changes in the temperature occurring during an experiment, and hence very different results were obtained according as to whether the general condition during the time of observation was rising or falling temperature. This lagging was therefore removed and a new protection constructed in the following manner substituted. A copper shield about 5 inches in diameter and made in two halves was fitted round the apparatus, leaving a 1½-inch space between the outside of the superheater and the inside wall of the shield. This was then insulated by a layer of asbestos paper on the outside, over which a coil of fine platinum wire was wound non-inductively, to act as a resistance thermometer. This wire was about 45 meters long and had a resistance of 250 ohms, changing by nearly one ohm for each degree of temperature. Over this was wrapped a second layer of asbestos paper on which were wound two coils of No. 16 Eureka wire in parallel to carry a heating current. A covering of asbestos paper completed the jacket, which could be maintained at any constant temperature by adjusting the heating current and could be very quickly heated or cooled. With the whole apparatus cold and no steam in the superheater, the jacket was raised to a steady temperature of 200 deg. C. in rather less than fifteen minutes.

During the experiments made with this addition to the apparatus, this jacket has been maintained at the mean temperature of the superheater, thus reducing the radiation loss almost to *nil*. There was, however, a serious loss still taking place by conduction to the condenser, which it was not possible to reduce without rebuilding the whole apparatus. This loss has been, however, kept constant for any particular temperature of the superheater, by always adjusting the cooling water through the condenser so as to give a temperature of 40 deg. C. at the outlet, which is at the end of the condenser near the superheater.

Two satisfactory sets of observations have been made, one with 250 watts dissipated in the heating coil of the superheater, and one with 350 watts. During these the superheat in the electrically heated superheater has been kept at 20 deg. C. by adjustment of the flow of steam, while the initial temperature has been varied from 150 deg. to 200 deg. C. by means of the gas heater on the steam pipe, the pressure being 4.3 atmospheres. The first of these sets of observations was made during the summer months and then the work was delayed for some time owing to alterations to the roof in connection with the extension being made to the laboratory, which necessitated the removal of the instruments to a place of safety. The second series was completed during the latter part of the year, and some check tests made after this agreed perfectly with those obtained in the summer. From these two sets of experiments the following values of the specific heat have been calculated.

Pressure = 4.3 atmos. Saturation temp. = 146.3 deg. C.

Mean Temperature.	Specific heat.
155 deg. C.	.532*
165 deg. C.	.497
175 deg. C.	.472
185 deg. C.	.455
195 deg. C.	.442
205 deg. C.	.432
215 deg. C.	.424
225 deg. C.	.417*

There still remained two possible sources of error which it was necessary to investigate. The first of these was the conduction of heat which might take place along the metal tubes of the platinum resistance thermometers. If this was considerable it would cause the hotter thermometer to read low and the cooler one to read high, thus making the observed value of the superheat much too low. Since, however, any value of the specific heat depends on the difference of two experiments at the same temperature, the effect of such an error on the final result would be small. To determine whether this error existed or not, one of the thermometers was removed and an Iron-Eureka thermo-junction put in its place. Two tests were made, similar to a previous experiment, and all the results agreed with this experiment so well that there does not seem to be any appreciable cooling or heating of the thermometers by conduction. The second and more important possible source of error was the throttling effect of the superheater. Although the superheater is amply large enough for the flow of steam, yet its bore is so filled up with the heating coil that considerable throttling seemed not only possible but probable. If the fall of pressure amounted to 2 lbs. per square inch, the effect on the value of the specific heat would be quite serious, as this error does not tend to eliminate itself on taking the difference of two experiments with different rates of flow. A second pressure gage was fixed to the end of the superheater and two series of observations were taken of the pressure of the steam on entering and leaving the superheater, one at a low rate of flow and the other at a high rate of flow. For these it appeared that the fall of pressure could not be more than 0.02 lb. per square inch, the effect of which is negligible.

During the year a second apparatus working on a modification of the same method has been constructed and is now ready for erection, together with a low reading potentiometer for use with Iron-Eureka thermo junctions. This apparatus does not use such large quantities of steam as the last one, but has the advantage of giving much quicker results and of reducing the radiation and conduction losses to a minimum.

* Extrapolated from the curve.

HOW TO CONSTRUCT A REVERSING COMMUTATOR FOR AN INDUCTION COIL.*

By A. FREDERICK COLLINS.

AN induction coil, however small, should be provided with a switch for making and breaking the primary circuit, and as it is often desirable to change

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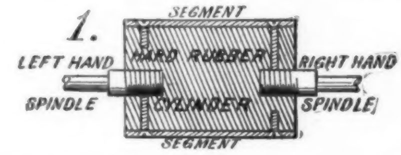


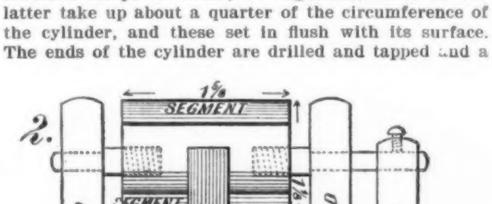
CROSS SECTION OF REVOLVING ELEMENT.

the direction of the current through the inductor, as the primary winding is called, a reversing commutator can be employed to an advantage.

In Great Britain and on the Continent the reversing commutator devised by Ruhmkorff is used extensively on coils of every size from the smallest to the largest, but in this country nearly all the small coils sold in the open market are provided with pole changing switches of the three-point pattern, while in large coils equipped with independent interrupters an interlocking switch is generally preferred.

The Ruhmkorff commutator comprises a solid cylinder turned of hard rubber or hard wood to which are screwed in grooves cut on oppositely disposed sides arcuated strips of brass, or segments; each of the latter take up about a quarter of the circumference of the cylinder, and these set in flush with its surface. The ends of the cylinder are drilled and tapped and a

2.



FRONT ELEVATION.

short brass rod is screwed in either end to form a spindle which in turn is supported by brass standards. To one of the ends of the spindle is attached a handle so that the cylinder can be rotated. On a line at right angles of the cylinder but placed parallel with it are two spring brass brushes supported at the base by brass blocks while the upper and free ends make contact with the arcuated brass strips or segments when the current is on, or with the surface of the cylinder when the current is off, as the case may be.

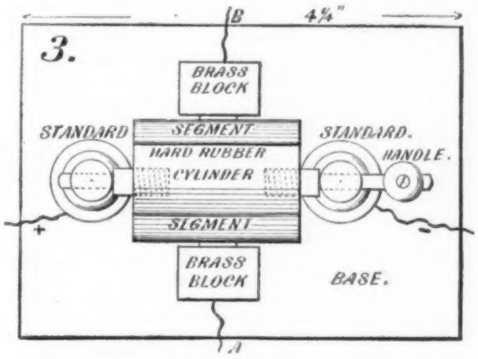
By referring to Fig. 1, which represents a cross section of the revolving element of the commutator, it will be seen that one of the brass strips is connected with one end of the spindle through one of the screws securing it to the rubber cylinder, while the opposite segment is likewise in connection with the opposite end of the spindle. The standards and the brass blocks may be secured directly to the bed of the coil or mounted on a hard rubber base, as preferred, the latter insuring the best insulation. A front elevation is shown in Fig. 2 and a plan view in Fig. 3, while the dimensions of the different parts may be ascertained from the following table:

TABLE OF SIZES OF PARTS FOR COMMUTATOR.

	Length.			
Hard rubber cylinder	1 5/8	Diameter. 1 1/8		
Brass commutator strips (2)	1 5/8	Width. 7/8	Thickness. 1/16	
Brass spindle (right hand)	1 3/4	Diameter. 1/4	Diameter of shank. 3/16	Length of shank. 1 1/8
Brass spindle (left hand)	1 1/8	1/4	3/16	1/2
Brass standards (2)	2 1/8	3/8		
Brass blocks (2)	3/4	Width. 1/2	Thickness. 1/2	
Hard rubber handle	1 7/8	Diameter. 3/4		
Spring brass brushes (2)	2 1/4	Width. 3/8	1/32	
Hard rubber base	4 1/4	3	1/2	

The hard rubber cylinder has ¼-inch holes drilled in both ends and tapped to receive the spindle rods; in each of the brass commutator strips two holes 3/32 inch are drilled in either end; in each of the brass standards a 3/16-inch hole is drilled 9/16 inch from the top while a ¼-inch hole is drilled and tapped in the bottom; in each of the brass blocks to which the spring brass commutator brushes are secured, two holes 3/32 inch are drilled and tapped in one side while two ¼-inch holes are drilled and tapped in the bottom; in the hard-rubber handle a 3/16-inch hole is drilled diametrically through, ¼ inch from one end, and at right angles to this and axially with the handle a ⅛-inch hole is drilled and tapped to receive a set-

3.



PLAN VIEW.

screw; in each of the brass commutator brushes two holes corresponding to those in the side of the block and having a diameter of 3/32 inch are drilled at one end. The holes in the base are drilled in accordance with the plan, Fig. 3.

In mounting the commutator the brushes are screwed to the brass blocks, and these in turn to the bed of the induction coil or the hard-rubber base. The left-hand standard is then secured to the bed or base, and the shank of the shorter spindle end is inserted in the bearing formed by the hole in the top; this done, the second standard is slipped over the shank of the longer spindle, when it is screwed to the base, and finally the handle is adjusted and the set-screw in its end is tightened up. A heavy insulated wire leads to each of the standards as well as to each of the commutator brushes through the screws holding these parts to the base. When completed the commutator presents the appearance shown in Fig. 4.

When the commutator is connected in circuit with

4.

COMMUTATOR IN PERSPECTIVE.

the primary helix of the coil and the source of electromotive force the positive terminal of the battery is joined to the left-hand standard as shown in Fig. 3, and the negative terminal to the right-hand standard. One of the brushes leads to one terminal of the pri-

* Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

mary coil while the opposite one leads to the other terminal through the interrupter.

Now since the brushes press upon the segments of the commutator and these are connected with their respective standards through the screws making contact with the spindles it is evident that when the handle is in the position shown in Fig. 2 the brushes will rest upon the oppositely exposed surface of the hard rubber cylinder and the circuit is broken; but if the handle is turned a quarter of a revolution to the right the circuit will be made and the current will, under the circumstances, pass from the positive terminal up the standard, thence through the spindle and screw to the commutator segment, and down the brush *A* to the primary coil. After energizing the latter it returns *via* the interrupter through the brush *B*, the segment upon which it rests, the screw, the spindle and the standard back to the negative pole of the battery. If, however, the handle is turned 90 deg. in the opposite direction the current will flow from the left-hand standard to the segment and brush *B* and returns through the segment and brush *A* and the right-hand standard, thus reversing its direction through the inductor.

PERNICIOUS EFFECTS OF ALTERNATING CURRENT OF HIGH VOLTAGE.

By Frederick H. Millener, M.D., E.E.*

The Niagara frontier has become the great center of mechanical electrical development, and it is destined to be at the head in this regard for many years to come. Naturally one would expect in this field, pregnant with all the possibilities of electricity, that there would be first observed such phenomena as might result from the presence of such immense quantities of this vital force as are now being procured here, just as one in the mining regions looks for conditions arising from the occupation of mining. This expectation has not been disappointed. We find the phenomena.

In this brief paper I shall present but one phase of the great subject of electricity and its relation to mankind having reference specifically to its pathologic effect upon the health and lives of men engaged directly in the manufacture, transforming, or transmission of this mysterious fluid. This discovery was suggested by chance, and my subsequent investigations have justified me in the belief that here is a subject which the medical profession will do well to take up and further analyze. The Roentgen ray was a chance discovery, and so are many of the discoveries which are afterward taken up by our profession and utilized for the benefit of mankind.

I have spent much time in observing the various manifestations of electricity, and most specially those arising from the alternating, as distinguished from the direct current. And the results have been that I have witnessed in many different ways, some wholly unexpected, manifestations of this subtle influence, this pernicious influence of the alternating current, especially when of high voltage.

I have made careful investigations in twenty-four cases of individuals suffering from this influence during the past few months, and the phenomena observed have been so remarkable, and at the same time so uniform and unvarying that I presented the results to the medical profession as I now do to the general public, in the hope that in a multitude of counselors there might be found the wisdom necessary to work out the efficient remedy. All of the facts detailed to me have been given voluntarily, and not as the result of questioning, for I was seeking light, and not trying to furnish it; and I am sure that the similarity of the symptoms points to but one conclusion, namely, that continuous employment in the immediate presence of these great electric generators or transformers, where one is continuously in an atmosphere heavily charged with electricity, or ozone, or some light or ray as yet undiscovered, results in such disturbed conditions of the digestive fluids or of the secretions of the stomach and its cognate glands and organs as greatly impair the digestive function; and that persons so employed lose their appetite, and become of an almost chalky complexion, experience pain and distress after partaking of food, and often have to obtain short periods of vacation in order to recover their ability to eat and digest food in a normal manner.

Every one has observed the exhilaration felt, not only by human beings, but by birds and animals, and even by insects, just before the electric storm. Children run and jump and caper on the lawn, or in the fields, and feel almost as though they could fly, young animals frisk and sport about, birds dart through the air, and the insect is specially conspicuous in his tantalizing efforts. But when the storm has at last broke, the lightning flashed, and the air is filled with ozone and other electric fluids, there is a feeling of depression, and every thing alive seeks to find some restful position and quiet place. When the storm has passed, normal conditions again return, and the air is said to have been cleared.

This is a common experience. Another common experience is to find, immediately after a thunder storm, that all the milk in the house has turned sour in an incredibly short time. Here we can plainly see that a chemical force has been at work. What is that force?

I have visited a number of dairies where they use separator machines, and I find that they invariably use the direct current, because souring of the milk does not occur where the direct current is used instead of the alternating current. The possible reason for this may be because of the fact that the direct current is a commutated alternating current and all the component parts of a true or natural current are not present. All up-to-date dairies have the direct-current machines, and in one instance I know of a dairyman who at an added expense of several hundred dollars installed a direct current machine, when he had been offered an alternating current at a remarkably low figure. The proprietor told me that he could not use the alternating current because he had found that the milk did not keep so well when they used a separator run by the alternating current as when it was run by the direct current.

I have many times visited the larger, in fact practically all of the great power houses and transforming plants in the entire Niagara frontier, notably those in Buffalo, Niagara Falls, Lockport, Niagara Falls, Ont., besides many of the smaller plants; but it is particularly of the large plants I speak where the manufacture of electricity or its transformation is the sole business.

I recently visited one of the power plants and the man in charge told me that after working for some time in the plant he found that tea and coffee did not agree with him. He drank no intoxicating liquors of any kind. He then tried bringing a bottle of milk with him to drink with his lunch, but the milk always turned sour before noon, although it was perfectly fresh when delivered in the morning. To test this I went to a nearby barn and milked about a quart from an obliging cow, and brought it to the plant, placing it where it would have the direct influence of the waste electricity from one of the large transformers. In less than an hour and a half it was sour, as the direct result of the chemical effect of the high voltage alternating current.

The man himself had been at work there for six months, and he said that when he came to the plant he was hearty, red-faced, full-blooded, and had a good appetite, good digestion, and was a perfectly well man. When I saw him his face and hands were of an almost chalky whiteness; he had no appetite, and when he ate his lunch, he nearly always felt distress from it in a short time, if he remained in the plant. Whereas, if he went home to lunch and stayed there during the afternoon, he had no distressing feeling. The same was as true of breakfast or dinner as of lunch. If he ate at home and then went to the plant, he would feel the distress just the same as if he had eaten at the plant.

This condition was not due in any degree to a sedentary life, for his work kept him very active, and he got all the exercise a man ought to have to keep well and healthy. Neither was it due to bad ventilation, as in these power plants there is always the very best of ventilation; windows and doors are open, and to test the currents of air in one of them I lighted a candle and found a uniform current of air from the outside inward toward the machines. These power plants are kept scrupulously clean. Drainage, lighting, heating, etc., are perfect. In fact no stove or heating apparatus is ever employed, as the waste energy, in the form of heat, which comes from the machines, is always found sufficient to keep the buildings warm. One might say that a power house was an ideal place in which to work, so far as all conditions of hygiene or sanitation are concerned. But there is this mysterious force flowing all around, about, above, below, and on every side. Is it ozone? Is it the Roentgen ray? Is it the violet ray? Or the ultraviolet ray? Or is it some ray or light that science has not yet observed? What is it that throws the digestive apparatus into such disorder? What is it that sours the milk? What is it that produces the chalky complexion?

These men are all at present able to work, but their work is not a pleasure to them. They are "off their feed," food does not agree with them, they suffer from the symptoms cited, and all, I believe, because of the pernicious effect of the alternating current of high voltage in and under the influence of which they have to perform their work.

I can add but little. I have stated a problem to the medical and electrical professions and the people in general. What the remedy will be I cannot predict. It may be some sort of a grounding of that wasted fluid that now fills the rooms of the power houses. It may be some neutralizing ray, or some form of insulation which can be devised and applied. It may be one of many things, but which one none of us is at present able to state. Perhaps this waste energy can be utilized for some form of by-products of electricity, or again, it may be employed for the artificial fermentation of milk or other fluids, or the more rapid aging of liquors.

But the important question is: What does this mean to the men engaged in the business of manufacturing electricity? It means personal discomfort and distress, which alone would make it enough of a problem to engage our most serious attention. It means that these men will be put in substandard lists for purposes of life insurance. It means, possibly, deterioration, more or less permanent, of the individual, of his vital organs, his powers of healthful assimilation of food, which in turn means anemia for the victim himself, and if he becomes the father of children, they will probably suffer the secondary effects of this unnatural condition of the parent.

The problem is of sufficient moment and interest to warrant the medical and electrical professions in giving it further study and investigation. If my article has the effect of awakening an interest in this problem, it will have served its purpose.

* Union Pacific shops, Omaha, Nebraska. Late Surgeon-in-Chief Nose and Throat Department, German Hospital Dispensary of Buffalo, N. Y.

[Concluded from Supplement No. 1632, page 26152.]

THE CHEMICAL COMPOSITION OF TOOL STEEL.*

MOLYBDENUM AS A SUBSTITUTE FOR TUNGSTEN IN HIGH-SPEED TOOLS.

Mr. White and the writer stated in our patent that molybdenum can be substituted for tungsten in modern high-speed tools, and that one part of molybdenum will produce approximately the same effect as two parts of tungsten. We also stated that molybdenum is not as satisfactory an element as tungsten to use in high-speed tools. The writer would repeat these assertions as giving our views at the present day upon the use of molybdenum in high-speed steels.

Under the head of "molybdenum substituted for tungsten" to the tools Nos. 55 (at the top of the list) to 63, inclusive (at the bottom of the list), it will be noted that, particularly in the case of tools Nos. 43, 54, 50, and 61, molybdenum tools having high cutting speeds were experimented with during the development of the Taylor-White process, and that from 4 per cent to 4½ per cent of molybdenum appeared to be a sufficient quantity to make a high-speed tool; whereas about 8 per cent of tungsten was required for this purpose. However, by noting our remarks made after most of these tools, it will be seen that they were brittle, had a tendency to fire crack, were weak in the body of the tool or else they were irregular in their cutting speeds. All of these faults are most serious in their nature, and they were at that time and are still regarded by us as so serious that when a tool clearly develops any one of these troubles we at once cease experimenting with it as not worthy of consideration among first-class tools.

The irregularity in molybdenum tools constitutes perhaps its most characteristic feature. By irregularities we mean that tools of the same chemical composition, and apparently treated alike, give large variations in cutting speed. We have as yet been unable to determine with certainty the cause for the irregularity existing in molybdenum tools. One explanation, however, for this trouble may lie in the fact that molybdenum tools appear to run at their highest cutting speeds when given a high heat slightly lower than the high heat required to produce a first-class tungsten-chromium tool. It may be that when the molybdenum tool is heated beyond that precise high heat which is necessary to make a first-class tool it suffers deterioration.

One of the most useful characteristics in the modern tungsten-chromium high-speed tool is that it requires little or no skill on the part of the blacksmith to heat it up close to the melting point, and that the tool itself shows clearly by its appearance when its high heat has been reached. Moreover, it is impossible to injure the cutting properties of these tools even if they are heated to a point at which the thinner or sharper edges begin to melt. The difficulty of judging by the eye an exact high temperature reached by a tool when close to or at its melting point is so great that if a definite treating temperature were required at these very high heats—that is, if tools were injured by heating beyond this temperature—much of the value of the high-speed tools would be lost.

Now, as stated, it appears likely that the irregularity in molybdenum tools may be largely due to the fact that a more accurate degree of high heat, considerably below their melting point, is required for them, and that this temperature must be closely judged by the eye of the smith, while no accurate judgment is required for the tungsten-chromium tools, because the tools themselves show when they are close to the melting point; and close to or at the melting point is the temperature which produces a tool giving the highest cutting speeds.

BEST MODERN HIGH-SPEED TOOLS COMPARED WITH ORIGINAL HIGH-SPEED TOOLS DEVELOPED BY US.

It will be a matter of interest to compare the various properties and chemical compositions of high-speed tools as developed by us at the time that our patent was written with those of the best of the high-speed tools that have been made up to the present time. Tools Nos. 26 and 27 are those recommended in our patent. By referring to their speeds in cutting, on the one hand, a medium steel, and on the other hand, very hard steel and hard cast iron, it will be seen that tool No. 26 gave the higher cutting speeds on hard steel and cast iron, while tool No. 27 gave the higher cutting speeds upon medium and soft steels. Thus, at the time of the writing of our patent, in order that a machine shop should have the best tool equipment it was necessary that tools made of two different chemical compositions be maintained as standards.

Referring now to tool No. 1 in Table I., the best high-speed tool experimented with by us in 1906, it will be noted that it has a higher cutting speed upon all the qualities of metal experimented with than any other tool. One of the gains, then, made by the latest high-speed tools lies in the fact that in one tool steel are combined all of the most desirable properties, and therefore only one need be adopted in a shop as standard.

We have previously referred to red hardness as the distinctive property of modern high-speed tools. Now, while red hardness is the most important property or quality sought for in high-speed tools, nevertheless, for certain classes of work—namely, turning the very hard qualities of steel and also hard cast iron—the property of hardness is desirable in addition to that of red hard-

* From "The Art of Cutting Metals," read by Fred W. Taylor, Philadelphia, before the American Society of Mechanical Engineers.

ness. The principal difference between tools Nos. 26 and 27 is that the former combines the quality of red hardness with hardness, while the latter lacks somewhat the quality of hardness, although it possesses red hardness in a higher degree than No. 26. The reason, then, that No. 26 cuts hard steel and hard cast iron at so much higher cutting speed than No. 27 is due to the fact that it adds the quality of hardness to that of red hardness. It must be borne in mind, however, that in the average machine shop more than nine-tenths of the work is done upon the medium or softer qualities of metal. Therefore, it is only upon a comparatively small class of work that the quality of great hardness needs to be added to that of red hardness in high-speed tools.

One property in which tools Nos. 26 and 27 were both lacking was that, although in cutting soft metals they made the same proportionate gains in cutting speed when taking the fine feeds as when taking the coarser feeds, still when these tools were cutting steel of even medium hardness but slightly higher cutting speed could be used with a feed finer than 1-16 inch than could be taken with a feed of 1-16 inch. This presented a really serious defect in our high-speed tools, because the greater portion of the feeds taken in the machine shops are finer than 1-16 inch.

Tools of the chemical composition of No. 1 were proved in our recent experiments (1906) to be capable of making the same proportionate gain in cutting very hard metals with fine feeds as they made when cutting soft metals with fine feeds. This, then, represents a second feature in which the latest high-speed tools are better than those originally developed; and this property is also due to the fact that the latest tool possesses a high degree of hardness in addition to its very extraordinary degree of red hardness. In the quality of hardness, however, it will be noted that tool No. 1 does not outstrip its nearest competitor to the same extent as it does in its extraordinary quality of red hardness, the gain in cutting medium steel being proportionately larger than the gain in cutting hard metals.

The third feature in which tool No. 1 is superior to tools Nos. 26 and 27 is that it is stronger in the body.

By far the most important improvement, however, in No. 1 tool over the original tools, Nos. 26 and 27 (a matter which the writer looks upon as of even greater importance than the 50 per cent increase in cutting speed), is the fact that it is much more difficult to injure No. 1 tool through carelessness in heating upon the grindstone or through overheating in the lathe under the cut than the original high-speed tools. The No. 1 tool will stand a surprising amount of overheating on the grindstone without very serious deterioration; whereas Nos. 26 and 27 were exceedingly sensitive to this bad treatment, and perhaps to this cause more than any other is to be attributed the great lack of uniformity in high-speed tools which existed in the early years of their adoption. For this reason, then, No. 1 tool marks a most important advance in maintaining the all-important quality of uniformity.

In our patent and in writing this paper we have referred to the good effects resulting from the second or low-heat treatment. The percentage of increase in cutting speed due to the second or low-heat treatment was more marked in the case of our original high-speed tools Nos. 26 and 27 than it is in the case of our latest high-speed tool, No. 1. With the original high-speed tools in many cases our low-heat or second treatment resulted in a gain in cutting speed of as much as 30 per cent, while in tools of the type of No. 1 the second treatment rarely resulted in a gain of more than 10 per cent, and frequently even not so large a percentage as this.

On the whole, we look upon this as a very great improvement in the latest high-speed tools over the original, because even if the new tools are not given the second or low-heat treatment at all, still they will be far more nearly uniform than the original tools of this class. Moreover, among those who have stolen and who are using the process of making high-speed tools, by heating tools close to their melting point, but very few have used in the past or are now using the second or low-heat treatment except in as far as this treatment is given to the tool through heating it incidentally or accidentally upon the grindstone or through heating it under the pressure of the chip in the lathe. The only feature in which tool No. 1 is less desirable than tools Nos. 26 and 27 is that it is more difficult to forge at the old forging heats—namely, about a light cherry red.

We have already pointed out that the substitution of chromium for manganese in both the old self-hardening steels and in the high-speed steels allows the tool to be forged at a heat very considerably higher than the light cherry red without danger of crumbling. In other words, the addition of the chromium and the absence of manganese render the tool just the opposite of what is called "red short"—that is, just the opposite of a liability to crumble when struck with a hammer at a high heat.

It will be noted that tool No. 1 contains from 5½ to 6 per cent of chromium, and this increased percentage of chromium has the very useful effect of allowing the tool to be forged at an exceedingly high heat—in fact, not very far below the melting point. The danger of injuring the tool through oxidization at this extremely high heat is great, however, and we therefore recommend as a forging temperature a light yellow heat. When tools containing from 5½ to 6 per cent of chromium and of the general chemical composition of No. 1 tool are heated to this light yellow heat they are much easier to forge even than the original high-speed tools, Nos. 26 and 27, and also easier to forge than such of the tools as lie between Nos. 2 and 23 and which contain less than 5 per cent of chromium. This is an added and a great advantage of No. 1 tool over the other modern high-speed tools. Tools of the composition of No. 1, then, should be forged at a light yellow heat.

To recapitulate, the improvement in the latest high-speed tools over the original high-speed tool consists in:

a. Far greater uniformity, owing to less danger in being injured in grinding and in daily use.

b. Fifty per cent increase in cutting speed.

c. The attainment of almost its maximum cutting speed without the necessity of the second or low-heat treatment.

d. The combination in the same tool of the highest degree of red hardness with a high degree of hardness, thus requiring only one standard high-speed tool steel in the shop.

e. The ability, owing to increased hardness, coupled with the necessary red hardness, to make the same proportionate gain when cutting with fine feeds upon hard metals as upon soft.

f. Greater strength in the body.

The only point of inferiority is increased difficulty in forging at a cherry red, and if blacksmiths are taught to forge their tools at a light yellow heat these tools are easier to forge than the original high-speed tools.

We have referred to the fact that since writing our patent no improvement whatever has been made in the heat treatment of high-speed lathe and planer tools. The all-round gain in the No. 1 tool over the original high-speed tool, then, lies entirely in a change in chemical composition. It would seem, therefore, a matter of interest to point out the change in the composition of these tools, and, so far as practicable, to indicate the cause and effect of the change in each of the improved elements.

PRINCIPAL CHEMICAL CHANGES MADE IN BEST MODERN HIGH-SPEED TOOL OVER ORIGINAL HIGH-SPEED TOOL DEVELOPED BY MESSRS. TAYLOR AND WHITE.

Our patent describing the original high-speed tool claims, briefly speaking, the combination of one-half of 1 per cent of chromium, or more, with 1 per cent of tungsten, or more; the tool to be treated to the high heat, etc. In our patent we also state that, practically speaking, the best tools developed by us at that time contained 2 to 3.80 per cent of chromium instead of 0.5 per cent of chromium, and 8 to 8.50 per cent of tungsten instead of 1 per cent of tungsten.

The principal chemical change which has taken place in the best high-speed tools up to the present time has been to increase still further the percentage of chromium, so that instead of containing 3.80 per cent as recommended by us, the tools now contain from 5.50 to 6 per cent, and to still further increase the tungsten from 8.50 per cent to from 18 to 19 per cent. This large increase in the percentage of chromium and tungsten has produced the material increase of 50 per cent in the red hardness of the tool and at the same time, also, a material increase in the hardness over our original high-speed tool No. 27. It is notable, however, that if the percentage of tungsten is increased much beyond 19 per cent, even though the chromium is also increased in quantity, the tool diminishes in red hardness. This fact will be noted by comparing the cutting speeds of No. 14 tool (which contains 24.64 per cent of tungsten and 7.02 per cent of chromium) with the cutting speed and chemical composition of No. 1 tool; and the metal close to the cutting edges of tools containing these very large percentages of tungsten and chromium appears to yield or become slightly deformed, particularly when cutting the thinner shavings or chips.

The presence of high manganese in a tool and also the presence of high carbon, both tend to increase the hardness of the tool. They make the tool more brittle in the body, and in addition high manganese causes the tool to crumble in forging when heated much beyond a bright cherry red. It was for this reason that we, in our original Taylor-White tools, specified low manganese (0.15 per cent), and this has been adopted as a characteristic in all the modern high-speed tools.

The tools as recommended in our patent contained carbon to the extent of 1.85 per cent, and this element has been lowered in modern high-speed tools largely as a result of the fact pointed out by us in our patent, that the quality of red hardness is not materially affected by either high carbon or carbon as low as 0.86 per cent. If either high manganese or high carbon (as much as 1.85 per cent) were used in a tool in combination with 5½ per cent of chromium and 19 per cent of tungsten, the tool would be brittle in the body and exceedingly difficult to forge, and the presence of high manganese particularly would tend to reduce rather than to increase its red hardness. Therefore the latest high-speed tools contain manganese in as small quantities as is practicable when the expense of the mixture and the needs in melting are considered.

Modern high-speed tools have been recently experimented with by us containing carbon varying from the small amount of 0.32 per cent to the higher percentage of 1.28, and our conclusion from these experiments is that the property of "red hardness" in the modern high-speed tools is not noticeably affected by either high or low carbon within these limits. The quality of hardness, however, in the tool is affected by the percentage of carbon and, as previously explained, a certain degree of hardness is required as a property in high-speed tools for several reasons.

The carbon contents of the modern high-speed tools, then, would seem to be governed by a compromise between the two requirements: On the one hand, higher carbon is needed to produce a greater degree of hardness in the tool, and, on the other hand, lower carbon is needed to make the tool more readily forged and also to make it stronger and tougher in the body.

As indicated in Table I., the analysis of tool No. 1, the best tool experimented with by us, contained 0.68 per cent carbon, and we recommend for a modern high-speed tool not less than one-half of 1 per cent (0.5 per cent).

There is one element of less importance than those previously considered which nevertheless should receive attention. The statement has been published several times that high silicon tended toward higher cutting speeds in high-speed tools. In developing our patent we experimented quite thoroughly with this element and arrived at the conclusion that high silicon tended toward lower cutting speeds, particularly when cutting the harder metals. In our patent, therefore, we recommended the low silicon, 0.15 per cent, and it will be noted that, on the whole, low silicon is a characteristic of most modern high-speed tools.

Our experiments indicate that high phosphorus and sulphur are much less injurious to high-speed tools than they were to the carbon tools. However, these elements still exert a somewhat injurious influence upon the steel, and we therefore recommend, inasmuch as the presence of chromium and tungsten in large quantities necessarily render high-speed tools very expensive, that the best qualities of low phosphorus and low sulphur iron should be used in their manufacture.

DISCOVERY BY TAYLOR AND WHITE THAT SMALL QUANTITIES OF VANADIUM IMPROVE HIGH-SPEED TOOLS.

No manufacturer of tool steel needs to be informed that the chemical analysis of steel (at least those analyses which are ordinarily made in our best chemical laboratories) is not alone a true or infallible guide to the real quality of steel. There are other factors than the elements which are ordinarily determined in laboratories which affect the quality of the tool steel.

We all know that to obtain the best quality of tool steel the mixture must be melted just right. The melting must be thorough and complete in order to bring about the proper alloying of the tungsten and chromium with the iron and carbon without at the same time oxidizing the bath. In addition to this, the metal must be poured or "teemed" in the right way in the molds, and the ingots must be made of the best size and shape for the subsequent operation of hammering the steel. The steel itself must be also carefully heated and handled during the operation of hammering. All of these elements affect the quality of the steel as well as the chemical composition.

Perhaps the most important of these collateral elements or influences affecting the quality of tool steel, however, is that of the melting and pouring or teeming of the ingot in such a way as to remove as far as possible those chemical impurities which are not indicated by the ordinary chemical analyses; and of these impurities we believe that the more obscure oxides constitute the worst enemies of steel. The term "good melting" might be translated into more scientific language by saying that the steel should be so carefully mixed and melted as to contain the minimum quantity of these injurious oxides. There have been various expedients adopted by makers of tool steel to secure this end, and some of these are still held more or less as trade secrets. It is our belief, however, that we have discovered during the last year perhaps the most efficacious remedy for "bad melting" that has yet been devised. We refer to the use of vanadium, a metal comparatively new in the art of practical steel manufacture. James M. Gledhill, in his paper on "The Development and Use of High-Speed Tool Steels," published in the Journal of the Iron and Steel Institute, in 1904, speaks of having substituted vanadium for chromium in high-speed tools, and he states that while the vanadium when used in cutting a steel of medium hardness stood well, yet it did not do better than tools containing the element of chromium.

Our experiments indicate the fact that vanadium should not be substituted for chromium, but that a very minute quantity of vanadium should be added to the mixture in melting, and that its use to the extent of from 0.15 to 0.35 per cent is as effective as higher quantities in the mixture. Our experiments would indicate the probability that the good effects of vanadium are derived from its chemical property as a cleanser of the steel during the operation of melting rather than as a very valuable property in the steel after it is melted. From 0.15 to 0.30 per cent of vanadium when mixed with the steel in the pot sometimes disappears entirely from the finished steel, and its presence cannot be found by analysis, indicating that it has probably joined with some other element, or elements, and gone off into the slag. It is likely, then, that minute quantities of vanadium act as cleansers of the bath, uniting with some of the obscure oxides and carrying them off into the slag. We know, for example, that the shop in which No. 1 tool was made is not run with the exceptional skill of long experience, and yet in this shop the addition of small quantities of vanadium very materially improves the cutting properties of the tool.

An illustration of this fact will be seen by comparing steel No. 18 with steel No. 19, these two steels being practically the same chemical composition except that one of them has had a small amount of vanadium added to it. These samples of steel were made in the melting shop above referred to.

To close the subject of the chemical composition for

high-speed tools, we do not wish to give the impression that we believe that No. 1 tool represents the chemical composition of the best tool which will ever be made. On the contrary, we believe that the improvement in the proper combination of the various elements required to make a high-speed tool will continue.

HOW COKE IS MADE.*

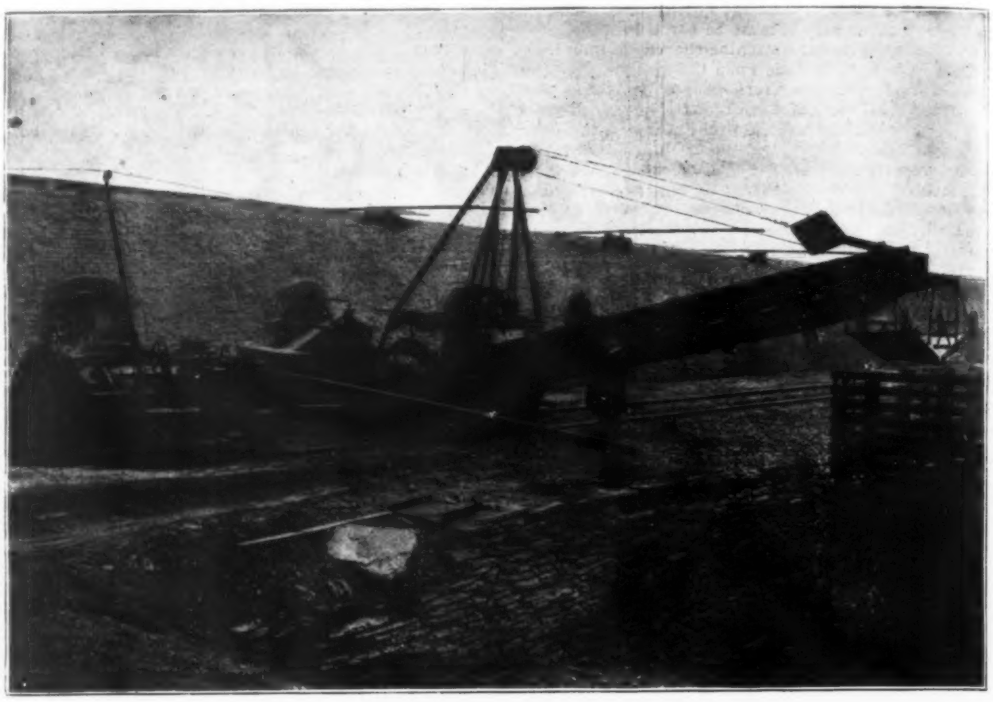
BITUMINOUS coal is converted into the coherent, carbonaceous substances called coke by a process of "dry" or "destructive" distillation, in which its volatile portions are driven off from the main body. The operation is carried on in the United States in beehive ovens, in Belgian or flue ovens, and in by-product ovens. Coal was formerly coked in heaps, piles, or mounds, or in open kilns, but these methods have become obsolete in this country. They are described in detail, and accompanied by illustrations in the Report on the Manufacture of Coke of the census of 1880. This report also treats at length of the beehive and Belgian ovens, so it will suffice to refer but briefly to these types here, especially as in their main features they remain practically unchanged to-day.

Beehive Ovens.—The beehive oven is built of brick or stone, is cone-shaped in the interior and has an exterior the shape either of a rectangular prism or with one or more of the sides slanting inward from the base. Coal is poured in and the gases escape through an opening in the top, while the coke is taken out through an opening in the face of the oven near the base, which also permits the proper amount of air to enter. To facilitate the withdrawal of the coke, the bottom of the oven is usually inclined toward the front. The standard ovens, designed by John Fulton, and used in the coking tests by the United States Geological Survey at St. Louis in 1904, were 12 feet in diameter and 7 feet in height. They are usually built in batteries for economy in construction, operation, and heating, and frequently two batteries are placed back to back within the same inclosing walls. The coal is charged into the oven through the top opening from a car or lorry running on tracks resting on the filling above the oven dome, and then is leveled off by a rake worked by hand or sometimes by a mechanical leveler, after which the door is closed by bricking up, leaving a few interstices and a small air space at the top above the level of the coal charge. The heat remaining in the oven brickwork from previous operations or from a preliminary heating up starts the distillation, and the evolved gas becomes ignited and burns with the air entering at the interstices in the door. By this means the arched dome of the oven is heated, and it reflects and radiates heat upon the coal below, thus continuing the decomposition until only coke remains. When the gas is burned off, water is turned into the furnace to arrest combustion and to give the coke a silver-gray luster, and the coherent mass is cracked so that it may be withdrawn. The coke is then drawn from the oven by hand rakes or by machinery, and the operation is repeated. The charge of coal used is from 4½ to 5 net tons of coal for a 48-hour coking period, and somewhat more for a 72-hour coking period, but in either case the oven is only partly filled by the coal, leaving a large space above it. The coking periods are usually so arranged as to avoid drawing coke on Sunday, two 48-hour charges and one 72-hour charge constituting a week's work. During the coking the coal gives off in the gas quantities of heavy hydrocarbons, which, in burning at the upper opening of the oven, emit great volumes of dense smoke.

* Abstracted from Bulletin 65, published by the Bureau of the Census of the Department of Commerce and Labor.

Belgian Ovens.—The term "Belgian ovens" includes a number of forms of coke ovens, among which may be enumerated the Dulait, the Coppée, and the Appolt. They differ radically from the beehive ovens in three particulars: (1) In the exclusion of air from the coking chamber, the heating necessary for coking being applied from the outside; (2) in the utilization of the waste heat and gases to facilitate the process of coking; (3) in their operation. Coking in beehive ovens proceeds from the top of the charge of coal downward, the heat is supplied by the combustion of the gases evolved from the coal and of part of the coal itself within the oven, and the coke is also quenched in the oven. Coking in Belgian ovens, on the other hand, proceeds simultaneously from the sides, bottom, and top of the coal charge inward toward the center, the heat necessary being supplied by the combustion in flues in the walls of the oven, of the gases of distillation previously collected, and the coke is quenched outside the oven.

The various types of Belgian ovens above enumerated differ in features of construction and in the arrangement of their flues. The Coppée oven, which is one of the best known, may be taken as an example of all. These ovens are built of brick in pairs, so that one may be charged as the other is ready to be discharged, and these pairs are grouped in batteries of thirty. Each oven is 26 feet 6 inches long, 4 feet high, and varies in width from 19 inches at the discharging end to 17 inches at the front. Connected with each oven are a number of vertical flues through which the volatile products of both ovens of a pair are conveyed downward to a horizontal flue under one of them. Then, after passing the length of this oven, the gases return by a similar flue under the other and enter a channel running at right angles to the ovens and under them, passing from this channel either directly into a chimney or under boilers where they are used to generate steam. Air is supplied to these vertical flues in the sides of the ovens by smaller vertical flues, there being one or two to each oven, connected with the top near the center charging hole, the air becoming heated while passing through the flue.



COKE DRAWER AND LOADER FOR BEEHIVE OVENS.

The ovens are charged through three hoppers in the top and are drawn by means of a mechanical ram propelled by a cogged driving wheel worked by a small portable engine. At each end of an oven are two iron doors moving on hinges and fixed securely in metal frames, the lower 3 feet high, the upper 1 foot. In working the ovens it is necessary first to heat them thoroughly, which is done by lighting fires of coal close to the doors at the end of every oven. When the ovens are sufficiently hot, they are charged. The first few charges of coal are in small lumps, the coke produced being of an inferior quality; but in a few days the ovens become so thoroughly heated that crushed coal of the consistency of very coarse meal is used, it being washed, if necessary, to remove impurities. When the charge is to be withdrawn, the front and back doors are opened and the mass of coke pushed out by a ram. The ram is quickly withdrawn and the two lower doors are closed. The oven is then charged immediately through the hoppers or openings in its top, and the coal is leveled with rakes by two men working through the upper doors at each end. The doors are then closed and carefully luted, and carbonization commences immediately. The processes of discharging and charging the ovens need not occupy more than eight minutes. The coke is quenched immediately on being withdrawn. Six charges are coked in each oven per week, each charge yielding about two tons of coke.

Weeks records the building of 80 Coppée ovens in 1880 at Goshen Bridge, Va., by the Iron and Steel Works Company of Virginia to coke coal from the New River region, West Virginia, and the operation of Belgian ovens in Illinois as early as 1872.

BY-PRODUCT OVENS.

In the "beehive" and Belgian ovens no effort is made to save any portion of the matter volatilized, yet the possibility of effecting this saving has long been known, for Goethe states that in 1771 Stauf, near Saarbrücken, endeavored in his "connected row of furnaces" to "cleanse the coal from sulphur for use in iron works" and "also turn the oil and resin to account, not even losing the soot," but that "all failed because of the many ends in view." According to Blauvelt, "it was not until 1855 that Pauwels, Dubochet, and Carl Knab, working on different lines, successfully operated coke ovens where the tar and ammonia were saved. A few years later Carvés added side flues to Knab's design, and the by-product oven in its essentials became a fact, although it was not until 1881 that the condensation of ammonia and tar was a success along with the production of a good quality of coke." This Knab-Carvés oven was the progenitor of the Semet-Solvay by-product oven, while the Coppée oven was the forerunner of the Otto-Hoffmann by-product oven. In the Census report for 1880, Weeks gives a detailed description of the Siemens, or Simon-Carvés oven as operated at Bességes, France, by the Terrenoire Company from 1867 to 1879, showing for each year the number of ovens operated and the yields. In 1879 they operated 96 of these ovens, coking 46,900 tons of coal and producing 33,092 tons of coke, 1,099 tons of tar, and 4,393 tons of ammonia-cal liquor. The yield of coal in coke was 75 per cent.

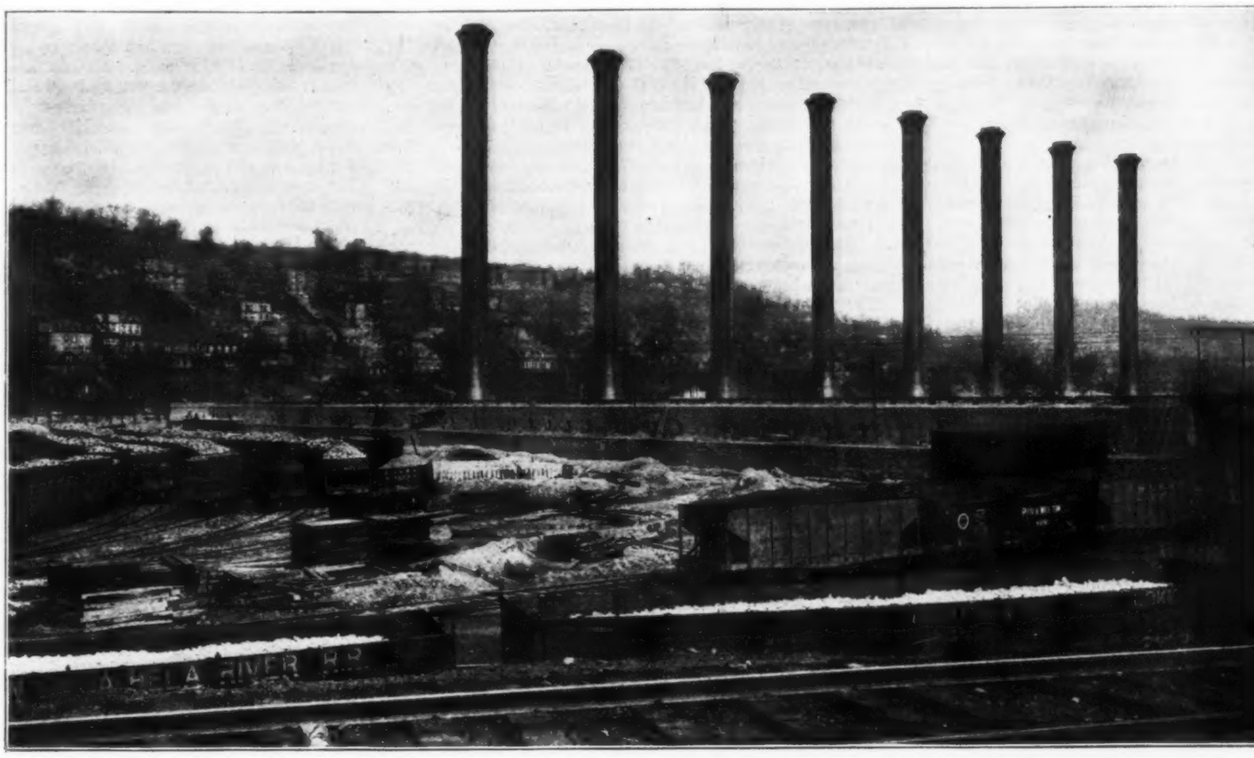
BEEHIVE OVENS AT UNIONTOWN, PENNSYLVANIA.

HOW COKE IS MADE.

No gas is accounted for, and about 35 pounds of "small fuel" was burned for each ton of coke produced. An itemized statement of cost of constructing 100 Carvés ovens is given, the total reaching about $192,-442.

The first known mention of the utilization of by-products from coking in the United States is the statement in the census of 1880 that the Consolidated Gas Company of Pittsburg collected the gas from beehive ovens and distributed it for lighting purposes. The first plant of modern by-product ovens built in the United States was a battery of 12 Semet-Solvay ovens erected at Syracuse, N. Y., in 1892.

Characteristics of By-product Ovens.—By-product ovens, such as are in use in the United States, are narrow rectangular cells with openings the full size of the cross section of the cells at either end, which, when in use, are closed by slab-like doors that may either slide vertically in grooves or be wholly detachable, and when put in place are sealed by luting with clay or by other means to make them gastight. These ovens are built largely of refractory brick, in batteries or blocks to prevent, so far as possible, loss of heat by radiation and convection, for when they are so built the heat of the adjacent ovens is necessarily interchanged. The coal in the ovens is carbonized by the heat produced by the combustion of gas in flues placed in the partition walls which divide the ovens in the battery, so that the process is one of destructive distillation pure and simple. The battery is placed above two systems of flues or regenerators. Through the first the combustible mixture of gas and air is led in to the combustion flues in the side walls of the oven. Through the second the gaseous products of combustion are led out to the chimney stack. By this arrangement some of the heat carried out by the products of combustion is utilized in heating the ingoing gases, thus not only effecting a saving of fuel, but also furnishing a higher temperature at the point of combustion than could be obtained if cold gases were used.

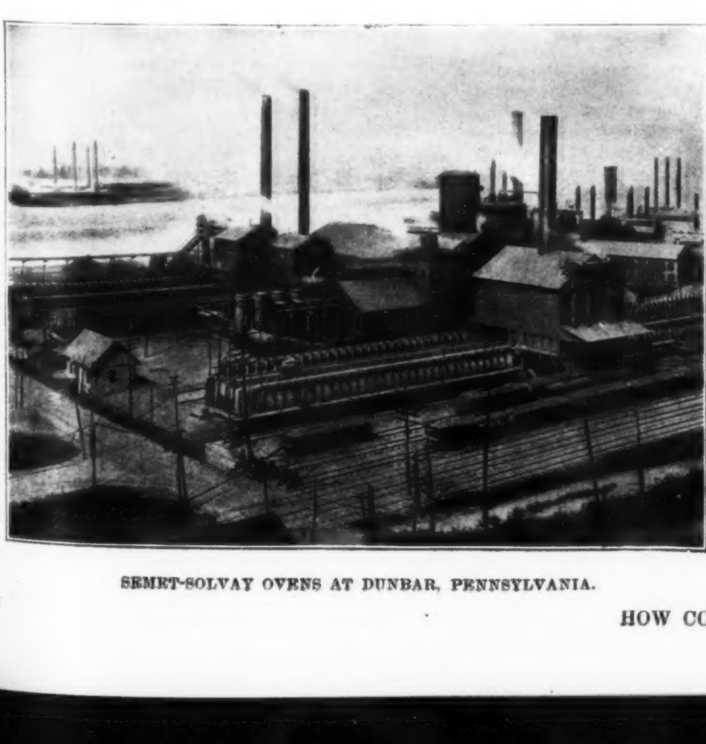


BEEHIVE OVENS OPERATED IN CONNECTION WITH LARGE STEEL PLANT AT PITTSBURG, PENNSYLVANIA.

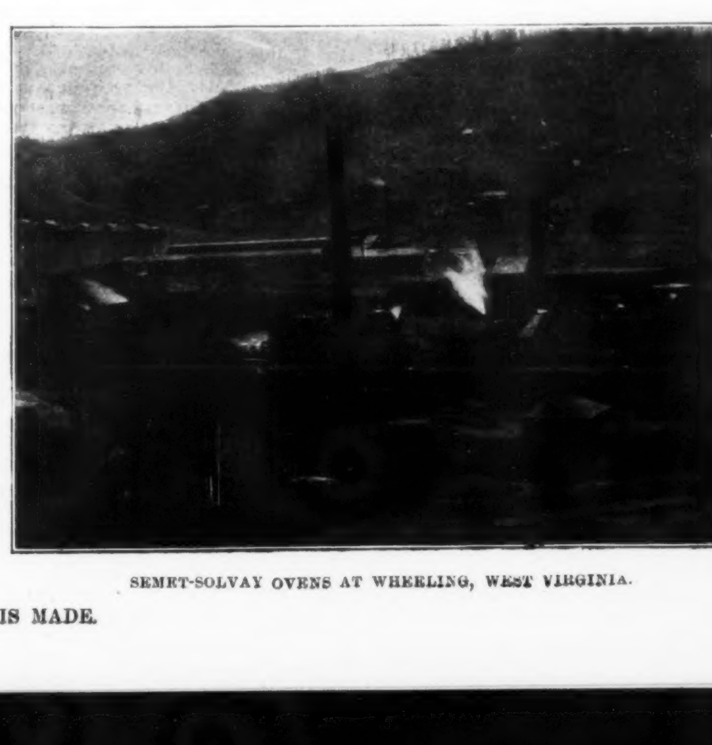
In the upper part of each oven are several openings through which the coal may be dropped in charging the ovens. In the top of the ovens are openings connected with mains through which the volatile substances produced by the distillation pass out and are carried to various reservoirs as they are separated by condensation into gas, ammoniacal liquor, and tar. These openings are usually at the extreme ends of the ovens just inside the doors. Where the gas produced is used as fuel gas only, there is but one of these openings and one set of mains, but where part of the gas is used for illuminating purposes and part for fuel, there are two openings and two sets of mains, so that during the first part of the heating, when rich gas is produced, this may be drawn off through one of the mains, and later when the lean gas is produced, this may be drawn off through the other main. In ovens of the class described the gas used for heating is a part of that produced in the distillation of previous charges of coal, but before it is used as fuel it is cleansed by scrubbing and condensing, as in the manufacture of coal gas.

As this process involves not only the production of coke but also the recovery and utilization of the gas, ammonia, benzol, and tar, a by-product plant includes not only the batteries of ovens, with their system of heating and the necessary ducts and mains, but also a recovery plant. First in importance in this system are the exhausters, which remove the gas from the ovens, draw it through the mains and cooling apparatus, force it through the scrubbing apparatus and deliver it to the combustion flues under pressure, or in case of rich gas, to the purifiers and storage gas holders. The control of the gas passing through the system centers in the exhauster room, wherein is placed the gage board on which are placed the pressure and vacuum gages, which indicate the existing conditions in the various apparatus. The exhauster is used because the slight pressure which is maintained in the ovens at all times, to prevent the leakage of air into them, is so variable that it would be unwise and undesirable to depend upon it to force the gas through the system.

First in order in the apparatus used in the treatment of the distillates come the air coolers, through which the gas is led to and fro in ascending zigzag passages, exposing large surfaces to atmospheric cooling. A number of these cooling units are arranged in parallel, so that any one of them may be taken off for cleaning or repairing without disturbing the operation of the remainder. They may be provided with an exterior sprinkling system, so that water cooling may be used in hot weather, when necessary, thus adding to the flexibility of the system. Next come the water coolers, which are rectangular in shape and filled with tubes to carry the water. The gas space is divided by successive baffles, so that a tortuous path is followed, and the circulating water is made to flow through the tubes in a parallel but opposite direction to the gas. After the gas has passed the air and water coolers, it is delivered by the exhauster to the tar scrubbers, where the tar which exists in finely divided particles in suspension in the gas, like a mist, is removed through friction and deposited in globules, by the passage of the gas through small openings in a series of thin steel diaphragms. When the coal yields considerable naphthalene, which may plug these openings, other devices must be employed. After the tar scrubbers follow the ammonia scrubbers, which, in the tower type, contain a latticework of wooden slabs, over which the water trickles downward while the gases rise; and then come the purifiers, which are rectangular boxes, containing perforated trays holding layers of lime or Laming's mixture, by which the sulphur and carbon dioxide are removed from the illuminating gas. Then follows the ammonia-recovery



SEMET-SOLVAY OVENS AT DUNBAR, PENNSYLVANIA.



SEMET-SOLVAY OVENS AT WHEELING, WEST VIRGINIA.

HOW COKE IS MADE.

plant, where the weak ammoniacal liquor is converted by distillation into concentrated crude liquor or into ammonium sulphate, and the benzol-recovery plant, where benzol is obtained from the lean gas by scrubbing it with dead oil. To these should be added the necessary gas holders, tar tanks, ammonia tanks, and other receptacles for holding the various materials and products, and sheds and appliances for storing and handling the coal used and coke produced.

Naturally, where the operations are conducted on so large a scale, it becomes possible to do by machinery much that in small plants is done by hand, and this is one of the economic advantages of the by-product plant. The mechanical appliances may perhaps be best referred to in a description of the method of operation.

Method of Operating By-product Ovens.—The coal is carried by conveyors from the storage pit to the storage bin above the battery of ovens, where it is drawn through chutes into the lorry, which travels on rails over the top of the battery. The doors of an oven having been closed and the oven having been heated, the manholes in the top of the oven are uncovered and the lorry brought over the oven, so that the coal in the lorry may be discharged into it. Through an opening in one of the doors the charge is leveled by a leveling bar, the oven is then sealed up, and the valve leading to the gas main is opened. When the coking period has elapsed, the valves to the mains are closed, the doors on either end of the oven are removed, and the charge is forced out by a ram or pusher, which traverses the oven and pushes the coke out onto a wharf or into a car on the farther side of the oven, where it is quenched by a stream of water.

To obtain water cooling the coke in some cases is received in a specially devised quencher, which consists of a rectangular box with cast-iron cellular walls. It is large enough to take in the whole oven charge and its bottom is formed of a motor-driven chain conveyor. The whole machine travels on rails parallel to the oven battery, and connection is made with the particular oven to be pushed by means of swinging doors and a drop bottom, which, assisted by the moving conveyor bottom, guides the coke charge to the conveyor. When the charge is received, the doors are closed and the coke is quenched with water. The immediate and violent generation of steam is taken care of by escape stacks. The whole receptacle is filled with steam, practically excluding the air, and the silvery gray color, characteristic of beehive coke, is thus obtained. When the quenching is complete, the coke is discharged into a car on the adjoining track.

The coal used in these ovens is fine coal, which not only facilitates charging but also permits the charge to pack closely, whereby the density of the resulting coke is improved. A modern practice in Europe for coals which had failed to produce a coke of sufficient density or strength is to compress the charge into a cake before loading it into the oven. In this case the coal is ground to the size of rice and moistened, so that it will cake slightly when compressed in the hand. It is then fed into a box somewhat narrower than the oven and stamped, layer by layer, by two or more stamps, which in some cases travel back and forth in the box and in others remain stationary while the box moves to and fro. When the box is full the coal has been compressed about 25 per cent. The box is now run onto a transfer car attached to the pusher, and then taken to the oven, where the sides of the box are removed and the coke pushed into the oven. The stamping of the coal prevents the formation of the spongy coke produced by certain coals and improves the physical structure as well. The process is not, however, advantageous for all coals, it being held that, when employed on coals which ordinarily produce a dense coke, the grain is made too close. A few installations for this method have been made in this country, but it has not as yet been generally adopted here.

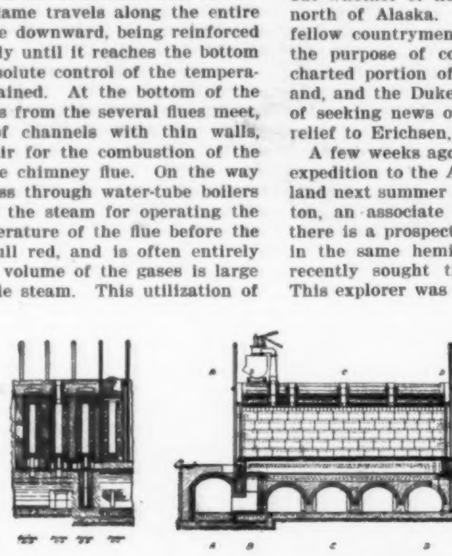
Semet-Solvay By-product Ovens.—The first Semet-Solvay ovens, 6 in number, were built for experimental purposes in 1882, near Mons, Belgium, and the results were so satisfactory that their use spread. In 1892 a battery of 12 ovens was built at Syracuse, N. Y., to which shortly after 13 more were added. This was the first plant of by-product ovens erected in the United States, but by January, 1906, there had been built or were being built in the United States 13 plants of Semet-Solvay ovens, embracing 1,295 ovens. The locations of these plants, the number of ovens in each plant, the character of the coke produced, and the use to which the gas is put is shown in the following statement:

SEMET-SOLVAY BY-PRODUCT OVENS BUILT OR BUILDING IN THE UNITED STATES, JANUARY, 1906.

Location.	No. of ovens.	Kind of coke.	Use of gas.
Syracuse, N. Y...	40	Kiln, foundry.	Fuel.
Dunbar, Pa.......	110	Furnace.	Fuel.
Sharon, Pa.......	25	Furnace.	Fuel.
Ensley, Ala......	240	Furnace.	Fuel.
Wheeling, W. Va	120	Furnace.	Fuel.
Detroit, Mich....	120	Furnace, foundry, domestic.	Illuminating.
Chester, Pa........	40	Domestic, foundry.	Illuminating.
Tuscaloosa, Ala.	40	Furnace.	Fuel.
Milwaukee, Wis.	160	Foundry, furnace, domestic.	Illuminating.
Lebanon, Pa......	9	Furnace.	Fuel.
Geneva, N. Y.	30	Foundry, domestic.	Illuminating.
Chicago, Ill......	160	Furnace, foundry, domestic.	Illuminating.
Steelton, Pa.	120	Furnace.	Fuel.

As marking the progress it may be noted that in 1893 the standard block of Semet-Solvay ovens was 25 ovens, having a coal capacity of 4.4 short tons each, or a total of 110 tons; in 1903 the standard block was 40 ovens, having a coal capacity of 7 to 9 short tons each, or a maximum of 360 tons; and in 1905 the standard block was 80 ovens, having a coal capacity of 9 short tons each, or a total of 720 tons. The length of the ovens has increased from 30 to 35 feet, and the height from 5½ to 9 feet, but though greater widths have been tried, an average of 16½ inches has been found most advantageous. The number of flues in the side walls in 1893 was three, in 1903 four, and 1905 five, the ovens being consequently spoken of as three high, four high, or five high. The time required for the treatment of a charge in 1893 was twenty-six hours; in 1903 the average was twenty-four hours; in 1905 it was eighteen hours; the shortening of the time being attributed to the introduction of machinery for charging and discharging the ovens and to the use of higher heats. The entire operation of discharging, charging, and sealing up an oven does not now occupy over fifteen minutes.

The Semet-Solvay system is distinguished by the use of horizontal flues formed either with small bricks or with hollow firebrick tiles; and by a special means for preheating the air for combustion, and sometimes the combustible gases also, by the waste gases of combustion. The hollow firebrick tiles are about 3 feet long and, placed end to end, they form the flues, while placed one on another, they form the facings of the side walls of the ovens. The flues are connected by an opening in the bottom placed near one end of each flue, so that gases and flames may traverse the entire length of all the flues. To heat the ovens, in a four high oven, for instance, gas is admitted at the ends of three of the four flues and meets hot air from the recuperators below. The flame travels along the entire series of flues, from above downward, being reinforced at each point of gas supply until it reaches the bottom of the oven, and thus absolute control of the temperature at any point is obtained. At the bottom of the oven the currents of gases from the several flues meet, pass through a series of channels with thin walls, thereby preheating the air for the combustion of the gas above, and out to the chimney flue. On the way to the stack the gases pass through water-tube boilers where they raise part of the steam for operating the plant, although the temperature of the flue before the boilers is not above a dull red, and is often entirely black. Nevertheless, the volume of the gases is large and generates considerable steam. This utilization of the waste heat of the combustion gases effects a considerable economy, as a large volume of steam is required in the treatment of the ammoniacal liquors. The air for supporting the combustion is drawn in by a chimney draft through a flue, where it is heated to a temperature of from 200 deg. to 500 deg. C. by gases of combustion which pass out in the flue below the oven. The air is admitted to oven flues and regulated by dampers so nicely and the gas supply is under such control that combustion takes place with the minimum amount of air and the temperature of the flues may be maintained at will from 900 deg. to 1,400 deg. C.



LONGITUDINAL CROSS SECTION OF FIVE HIGH SEMET-SOLVAY OVENS.

The advantage claimed for the Semet-Solvay method of construction is that the hollow flues forming the walls of the oven are entirely independent of the side walls. These side walls, made of firebrick, carry the huge mass of brickwork, coal cars, etc., above the oven proper and thus relieve the flue-structure bricks from all strains and thrusts, which would have a tendency to displace them, causing leaks deleterious to the gas and other products. Because of the freedom from burden, the oven sides of the flues can be made much thinner than they otherwise could, so that they conduct the heat from the flue where the combustion of the gas takes place to the mass of coal in the oven more advantageously. The thick side walls and the mass of brickwork above serve to hold the heat, giving it up to the oven during the time of discharging and charging, thus preventing any chilling of the oven. An expansion space above the oven permits the tile to expand without affecting the main body of brickwork. Moreover, the horizontal arrangement of the flues and the admission of the gas at several points permit an easy control of the temperature of all parts of the coking chamber, and a ready inspection of the whole length of every flue to determine whether the temperatures are controlled and distributed properly. This point is of great importance, since it insures the whole mass of coal being thoroughly coked, and in the minimum time, without any danger of overheating any part of the oven structure. In fact, a uniform and accurately controlled temperature in the oven chamber is essential to the best coke in the shortest time.

(To be continued.)

Steam turbines are to be used in the Frency navy upon six battleships of the new naval programme. Following the report of the special commission which was sent to England a few months ago, the Minister of Marine decided to use Parsons turbines upon the torpedo destroyer "Chasseur," which is in construction at the docks of Normand Brothers at Havre. The same firm also built the torpedo boat "No. 293," which is equipped with the same type of turbines. As regards the steam turbines to be used on the destroyer, they are now building in the factory of the "Electro-Mecanique" Company of Bourget, near Paris, who have the exclusive rights for the Parsons wheels in France. The Minister not long ago made arrangements to have the new battleships built. The orders for the six vessels are divided among the State arsenals and the leading private docks, among which are the Société des Forges et Chantiers of the Mediterranean and the Saint-Nazaire-Penhoet docks. These two companies, which are the only ones having a license from the Electro-Mecanique firm for building the Parsons wheels, will thus be called upon to build the turbines for their own as well as for the other vessels. The displacement of the new battleships will be 18,350 (long) tons and the speed is 19 knots. About 22,500 horse-power is expected from the turbines. There will be eight steam turbines operating four screw shafts and the latter will work at 300 revolutions per minute.

AN ANTARCTIC PROBLEM.

AT least two projects for exploration in the northern hemisphere will command popular interest this year, and perhaps next. Commander Peary's and Mr. Wellman's plans are too well known to call for specific mention here. Capt. Mikklesen, a Dane, will continue the campaign, begun in 1906, with a view to finding out whether or not there is land in the Arctic Ocean north of Alaska. Capt. Erichsen, one of Mikklesen's fellow countrymen, landed in Greenland last year for the purpose of completing the survey of a yet uncharted portion of the northeastern coast of that island, and the Duke of Orleans announces his intention of seeking news of the latter's success and extending relief to Erichsen, if necessary.

A few weeks ago there were indications that a fresh expedition to the Antarctic continent would leave England next summer under the leadership of Mr. Shackleton, an associate of Capt. Scott five years ago, and there is a prospect that another venture will be made in the same hemisphere by Mr. Arctowski, who has recently sought the necessary support in Antwerp. This explorer was a member of the Belgian expedition of 1898-99, which operated to the southward and southwestward of Cape Horn, and he purposes to begin where De Gerlache's inquiries left off and devote himself to a region bordering on the Pacific, and as yet little known.

By far the deepest and perhaps the most remarkable indentation of the Antarctic continent was found by Ross more than half a century ago, in the vicinity of Australia and New Zealand. He pushed his ships into it as far as the 78th parallel of latitude, and discovered and named the volcanoes Erebus and Terror. He was convinced that further progress was made impossible by a stretch of coast running nearly east and west. Well, so it was for ships, but Scott, in 1902 or 1903, found that beyond the edge of the ice barrier, which had a vertical face 200 or 300 feet high, was a surface resembling that of a glacier. It was on this that he made his boldest push in sledges toward the pole (to latitude 82:17), skirting the coast of Victoria Land, which here runs north and south and forms the western boundary of what is called the Ross Sea. Scott succeeded in getting his own vessel over near what seemed to be the opposite shore, three hundred or four hundred miles to the eastward, and named the land which he observed there after King Edward VII.

How much farther south this remarkable bay or strait reaches is a profoundly interesting problem. Under the most favorable circumstances it may never be navigable beyond the point where the "Discovery" went into winter quarters, but it apparently offers much the most practicable route for sledges and automobiles to the pole. Since Mr. Shackleton will approach the Ross Sea by way of the Indian Ocean, it may be presumed that he will follow the coast of Victoria Land pretty closely when he temporarily abandons his ship and resorts to other means of transportation. If Mr. Arctowski, who would approach from the Pacific, fully executes his present purpose, he will visit King Edward VII. Land and complete the work left unfinished by Capt. Scott. He, too, evidently wants to reach the pole, and he has considered the feasibility of using an automobile for the last stage of his journey. Even if his principal ambition were not realized, he might be able to supplement in a large measure the work already done in that quarter. Considerations of international courtesy may restrain him from invading the field simultaneously with Mr. Shackleton, but the world would welcome anything he found it possible to do with propriety.—N. Y. Tribune.

ALCOHOL AND MOUNTAIN CLIMBING.

By Prof. A. DURIG.

LAST summer I made some experiments by a novel method on the effect of alcohol on the capacity for work, especially in mountain climbing.

From the volume and the chemical constitution of the products of respiration it is possible to determine the activity of oxidation in the body and the quantity of proteids, fats, and carbohydrates actually consumed. The unit of heat, called the calorie, is the quantity of heat required to raise by 1 deg. C. the temperature of one liter of water. In terms of energy, a calorie is equal to 427 meter kilogrammes, or the work involved in lifting 427 kilogrammes one meter against gravity. The number of calories produced by the combustion or oxidation of one gramme of each of the following substances is: Fat, 9.5, starch, 4.18, alcohol, 7.07.

The energy required for the performance of a given labor may be supplied by the oxidation of either fats or carbohydrates. We had determined by preliminary experiments the quantity of fats and carbohydrates, taken together, required for making each of the ascents used in the main experiments, and had arranged our rations accordingly, varying at will the proportions of fats and carbohydrates but taking care to provide a sufficient number of calories. The fact that our weights remained nearly constant proves that the calculation was approximately correct. The question in regard to alcohol was, whether a moderate quantity of alcohol could be substituted for a quantity of fats or carbohydrates capable of furnishing by oxidation an equal number of calories, without impairing the performance, greatly increasing the cost, or producing injurious effects.

The energy expended in mountain climbing may be divided into three parts. If a man weighing 80 kilogrammes ascends a mountain 2,000 meters high, the work of ascent, in the narrowest sense, is $80 \times 2{,}000 = 160{,}000$ meter kilogrammes. To this must be added the work of traveling the horizontal distance from the start to the finish and also the energy that would be consumed by the man at rest during the time occupied by the journey. From the volume and composition of the air exhaled in a given time when the man is lying in bed, walking on a level, and making the ascent, respectively, the consumption of oxygen, the production of carbonic acid, and hence the expenditure of energy can be determined in each of the three cases. The result in the first case is the energy expended while at rest. This, subtracted from the second, gives the "horizontal component" of the energy. The work of ascent, or "vertical component," is obtained by subtracting the second result from the third.

In the combustion of carbohydrates in the body or elsewhere the volume of carbonic acid produced is equal to the volume of oxygen consumed, but in the combustion of fats only 0.707 volume of carbonic acid is produced for each volume of oxygen consumed, because in fats some of the hydrogen must be oxidized in addition to the carbon. Hence, when a mixed diet is used the "respiratory quotient," or the ratio of carbonic acid produced to oxygen consumed, will fall somewhere between 1 and 0.707, and from its particular value in any experiments the proportions of fats and carbohydrates oxidized can be deduced. From these results and the total amounts of carbonic acid the quantities of fats and carbohydrates oxidized can be separately computed. The total heat of combustion, in calories, can be obtained by multiplying the number of grammes of fats by 9.5 and the number of grammes of carbohydrates by 4.18, and adding the products. Finally, the energy furnished by oxidation can be computed in meter kilogrammes by multiplying the above number of calories by 427.

The ratio which the effective work (the sum of the rest, horizontal, and vertical components) bears to the total energy furnished by oxidation is called the efficiency of the diet used.

The apparatus employed in measuring the volume of air exhaled, etc., weighed 18 kilogrammes, or about 40 pounds, and was carried on the back of the walker. Its principal, or at least its largest, part is a gas meter of the ordinary dry type. The nose of the walker is clamped and all inhalation and exhalation are performed through a mouthpiece connected with a branched tube. One branch terminates on the left shoulder, in an inhalation valve which permits the ingress but not the egress of air. The other branch leads to an exhalation valve (on the right shoulder) which admits the exhaled air to the meter, but prevents any return flow. Two thermometers give the temperature of the exhaled air. The interior of the meter communicates with the top of a glass tube, of which the bottom is connected by a long rubber tube with an unstoppered glass flask. The flask and tubes are filled with liquid. The flask is suspended by a cord which is wound on a reel connected with the registering mechanism of the meter. As this mechanism is driven by the current of exhaled air the flask is lowered, and the level of the liquid in the glass tube is lowered with it. The result of this is that the glass tube is gradually filled with exhaled air, a specimen of which is thus collected for examination. When the tube is filled with air it is closed at both ends and removed. The filling of the tube, which receives only a small proportion of the exhaled air, may occupy twenty minutes. During this period observations are made of the time, the barometer and thermometers, and the distance and elevation accomplished. Another tube filled with liquid is then inserted and the flask raised, so that another specimen of air can be collected. The path had previously been surveyed and set with monuments of distance and elevation.

The respiratory quotient—the ratio of the carbonic acid produced to the oxygen consumed—steadily decreased during the ascent and even during the descent, or return journey, and if the ascent was repeated on the following day by the same person the value of the quotient at the start was less on the second than on the first day. This proves that the carbohydrates are consumed first and that the fats are drawn upon more and more as the supply of carbohydrates diminishes. A day of rest was required to bring the value of the quotient at starting to its original or maximum value.

After the walker had become habituated to the exercise it was found that 3,416 meter kilogrammes, equivalent to about 8 calories, of energy of combustion were developed for each 1,000 meter kilogrammes of work performed. The efficiency consequently was about 29 per cent.

After these preliminary experiments, from 2 to 2.5 fluid ounces of alcohol, equivalent to about a pint of wine, were taken before the ascent by the walker, who was neither an abstainer nor a hard drinker but a man accustomed to taking similar quantities of alcohol.

The results of a number of ascents made with and without alcohol were that alcohol diminished the amount of work performed per minute by about a sixth (from 1,215 to 1,009 meter kilogrammes) and diminished the efficiency by about an eighth (from 29.5 to 25.5 per cent).

On the whole, the experiments proved that alcohol is oxidized in the body and can replace other substances, especially carbohydrates, and afford energy for muscular labor, but that the quantity of alcohol required to produce any considerable amount of energy is too great to be taken with safety. (About half a gallon of spirits would be required to furnish the whole work of a day's mountain climbing.) It was also proved that alcohol is less economical (without regard to cost) than other foods, as it has a lower efficiency, or, in other words, involves a greater waste of energy. Hence, though alcohol is theoretically a food, it has no practical value to the worker as a source of energy.—Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from Umschau.

EUTECTIC ALLOYS RESEARCH.

THE National Physical Laboratory proposes to investigate the physical structure and mechanical and thermal behavior of eutectic alloys. At the present moment there is a marked gap in our knowledge of these bodies. The physical structure of pure metals and the changes which this structure undergoes when the metal is mechanically deformed, as also the process of crystallization and crystal growth both at and below the freezing point, have been very carefully studied, principally by the aid of the microscope, by a number of investigators, and the conclusions reached command wide acceptance. The eutectic and "eutectoid" bodies are, however, not nearly so well understood and have been very little studied from this point of view, probably because their usually minute structure renders the study more difficult than in the case of pure metals. It is thus at the present moment an open question whether the structure of "eutectic" and "eutectoid" bodies is, like that of pure cast metals, truly crystalline or not—the phrase that at a certain temperature an "eutectic crystallizes" being based chiefly on the analogy of homogeneous bodies such as pure metals or solid solutions. Even if the generally crystalline character of these bodies be admitted or assumed, the detailed nature of the crystalline arrangement remains to be determined so as to decide whether there is any uniform crystalline orientation throughout a "grain" consisting of many lamellæ of both constituents of the eutectic, or whether each lamella is an individual crystal. Spherulitic structures may also occur. It is further to be decided whether eutectic bodies are alike in this respect or whether different modes of solidification prevail in different groups of elements. In another aspect of the same question, the thermal behavior of the eutectic alloys is to be studied; it is well known that by suitable thermal treatment the two constituents may be caused to separate or segregate more and more completely, and it is important to determine the course of the process of fusion in such a case, i.e., to determine whether the melting point is raised by such segregation and what intermediate stages—if any—occur prior to actual fusion: the study of transition products in the formation and fusion (or absorption) of eutectic or eutectoid bodies is of special interest in connection with the less known structural constituents of steel ("sorbite" and "troostite"); it is hoped, however, that careful study of these phenomena may throw some light on the cause of the relatively very low melting points of the eutectic alloys. The problems here indicated are only those arising upon preliminary consideration of the subject, but numerous other questions of interest are likely to arise in the course of a research of this kind. For this and other obvious reasons, no very definite plan of experiments can be laid down, and even the methods of investigation are likely to require modification and development as the research proceeds. The methods of attack now contemplated are the following:

1. Preparation of as great a variety of "eutectic" and "eutectoid" bodies as possible in a state approaching purity—including the exact determination of their composition and melting and freezing points. Of the series so prepared characteristic members are to be selected for further study.

2. Study of the micro-structure of the eutectic bodies and the effects of slow and rapid cooling and other heat treatment on the structure.

3. Study of the microscopic effects of strain upon these bodies as differently treated; microscopic study of the mechanism of plastic deformation and of the path of fractures produced in various ways—the results being correlated, where possible, with the mechanical properties of the alloys in various conditions. 2 and 3 above make a very severe demand upon the capacity of the microscope, since it is probable that some of the features to be observed lie at or even beyond the limits of ordinary microscopic resolving power. The limits of microscopic resolution have, however, recently been pushed considerably further by the introduction of microscopic appliances for the utilization of ultra-violet light of short wave length (0.275μ), yielding *effective* magnifications up to 3,000 diameters, and it is proposed to apply this apparatus to the study of the minute features referred to above.

4. The processes of solidification and fusion to be studied thermally and microscopically, by means of heating and cooling curves and by the examination of specimens suddenly cooled at intermediate stages of both processes.

5. The formation of eutectic bodies without the intervention of fusion, i.e., by diffusion of solid metals with and without the aid of pressure, and by electrodeposition and study of the structure and properties of the bodies so formed.

6. Formation and study of ternary and quaternary eutectic alloys.

REASONS FOR BELIEVING IN AN ETHER.*

By DANIEL F. COMSTOCK.

MANY scientific men who are not physicists feel an ill-defined distrust of some of the more or less complex conceptions of modern physics. They feel that the physicist has, perhaps, allowed his imagination to carry him too far and has not stopped often enough to re-examine the foundations of his faith.

Perhaps the most fundamental conception exciting some such distrust from the outside is that of the ether which is assumed to fill all space. The non-physicist who has read of the oft-repeated but entirely unsuccessful attempts to detect the "ether wind" due to the earth's movement through space, and of the negative results of all "direct" experiments on the ether, begins to feel that the builders of physical theory are perhaps unreasonably tenacious of an idea which could, perhaps, best be dispensed with.

It may not be out of place, therefore, to state as briefly and clearly as possible several reasons for belief in an ether, reasons sufficient because based directly on observation or experiment.

The most important evidence is the simple fact that *the velocity of light does not depend on the velocity of the source.* This is shown by the normal apparent shape of the orbits of binary stars, which, it is easy to see, would otherwise appear distorted. For, if the orbital velocity of one member of a binary star affected the velocity of its light, it would affect the time required for the light to reach us and would, therefore, change the apparent position of the star at any instant. The resulting distortion, which in some cases would be great, has been carefully looked for but has been found absent.

Thus it is a fact founded on observation that the velocity of light is independent of the source. The meaning of this fact can be made clear in the following way. Suppose an observer imprisoned in a windowless box which is thrown at random into space. Such an observer, meeting no experimental difficulties, could discover and accurately define his speed through space by simply measuring the velocity of light in various directions within his inclosure, and this, be it noted, without any reference whatever to any outside body. In general, he would find that light travels faster across his box in one direction than it does in another, for, as we have seen, the real velocity of light in space is not affected by the motion of the light source which he carries, and hence a change in his motion would change the apparent velocity of light within his box.

Thus space possesses what we might call a "positional" property, by means of which the magnitude of any motion can be defined without reference to any body in the universe, and this motion is what physicists call "motion with respect to the ether."

There is an entirely different experimental truth which leads to the same conclusion as the above.

It is a generally accepted truth that two similarly charged bodies when moved side by side have, superimposed upon their mutual repulsion, an attraction which depends upon the fact that when moving they act like two parallel electric currents. This follows from Roland's classical experiment.

Now if the two charges, stationary with respect to each other, are considered alone in space, it is evident that they furnish our imprisoned experimenter another means of finding his motion relative to space, for the strength of the above-mentioned attraction depends only upon this absolute motion. This leads to the same conclusion as formerly, that space has a "positional" property.

Other evidence of a similar kind might be given, but the above is sufficient to make it clear that at least so far as it represents this positional property of space the conception of an ether is thoroughly legitimate.

A being from a planet which possessed no atmos-

* Science.

phere, if he came to earth, might first become conscious of our atmosphere through feeling it set in motion relatively to himself when he moved. In a somewhat similar way the ether manifests itself, since we know it through its motional property.

We are conscious of matter only as a collection of properties and one of these properties certainly is that it is capable of marking position. Therefore, the unknown reality, which exhibits this positional attribute in space as one of its properties, can be said to resemble matter to this limited extent at least, and upon this sure foundation can fitly be based the physicist's conception of an ether.

FOUNDATION PROBLEMS IN NEW YORK CITY.

By C. M. Ripley, E.E.

The gigantic increase in erection of skyscrapers in the "Lower Broadway" section of New York city during the past few years, has been made in the face of grave and increasing engineering difficulties. A study of the laying of the foundations for the building of the Trust Company of America (Fig. 1) now nearing completion in the financial section of Wall Street, will bring out forcibly (1) what these problems are, and (2) how the resourcefulness of engineering contractors has been developed. Less than a dozen years ago, the following conditions would have been considered insurmountable obstacles, making impossible the construction of a twenty-five story building on this site.

As shown in the accompanying plan (Fig. 2) this building is situated between the present United States Trust Company and the Mills Building. Owing to the prevailing prices of Wall Street real estate, every inch of available space must be utilized, with the result that the foundations of the new building must practically "rub elbows" on either side with those of the old.

Geological Difficulties.—It is not generally understood that as we approach the southern end of Manhattan Island, the bed rock slopes off lower and lower below the surface—so much so that at Wall Street it is 80 feet below the curb, and at the Battery between 90 and 100 feet below. It might be mentioned in this connection that the rock appears at water line at about 14th Street, and continues rising as we approach upper Manhattan; so that in building projects in this latter portion of the city, it is often necessary to blast away a miniature mountain before the site is even down to street level. It is due to this characteristic of New York's geological formation, that the excavation for the great Pennsylvania Railroad depot has so often been termed a veritable "quarry." In these cases the foundations are supplied by nature.

In striking contrast to such simple foundation problems, we have the case at hand—foundations to be laid to bed rock, through about 80 feet of quicksand and water-bearing strata already heavily loaded by adjoining ten-story buildings. In digging, water and soft mud is encountered but a few feet below the street level. Were this soft muck pumped out or removed by any of the old-time methods, more of this fluid material would enter the excavation from either side, and the adjoining structures would settle and later collapse. The constructors to whom was intrusted the responsibility both of planning and doing this work, solved these problems by employing the pneumatic caisson process, in conjunction with the Moran air lock, invented by Mr. Daniel E. Moran, C. E.

Underpinning Adjoining Buildings.—The principle of the air lock was used for the underpinning of the adjoining buildings as well as for the main part of the work. Fig. 5 shows how work was begun even while the old building was being wrecked. Niches about 5 feet above the cellar floor and 5 feet wide were cut

Fig. 1.

in the walls of the adjoining buildings with electric and steam drills at intervals of about every 6 to 9 feet. These were carried downward through the old foundation, and through the sand under the foundation until the water line was struck. Then one 6-foot length of riveted steel pipe, 36 inches in diameter, was jacked down into the sand, thereby employing the weight of the building in constructing the new underpinning. A downward-opening door was installed at the top of this length, a second length was bolted to the first, and then the second downward-opening door was installed, completing the miniature air lock. As shown in Fig. 5, compressed air was supplied to the bottom chamber, and the work pushed lower and lower through quicksand or hardpan, as successive lengths of pipe were bolted to the top and material excavated. When rock was reached the entire cylinder was filled with concrete, the steel pipe remained, and when the steel beams were placed as shown in the left side of Fig. 5, the underpinning at that point was completed. Twelve of these concrete cylinders support the wall of the Mills Building, and eleven that of the United

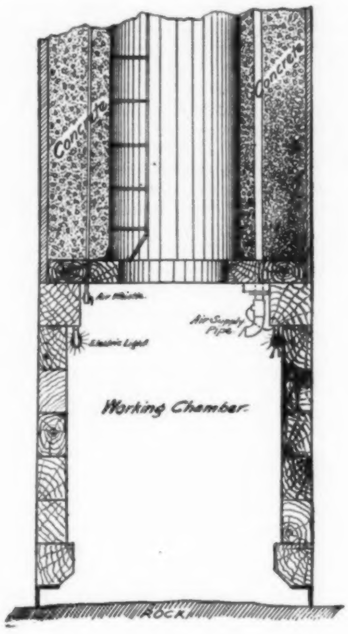


Fig. 3.

States Trust Company Building, as shown by the circles in the shaded portion of Fig. 2.

Twenty-seven concrete piers constitute the foundation work proper under the Trust Company of America Building. The remarkable speed with which these piers were sunk to bed rock was made possible mainly from this one fact: The air lock used allows the material excavated in caisson to be hoisted to the open air in one continuous haul, being handled but once in transferring from bottom caisson up to the dumping place, generally a truck.

The square and rectangular spaces shown in Fig. 2 give the location of the concrete piers on the site of the Trust Company of America Building. In Fig. 6 is shown the four-boom traveler derrick, which is equipped with four double-drum hoisting engines, and which effectively covered the entire area. It served to place the caissons, one of which weighed 20 tons and was 14 x 31 x 8 feet high, at their proper location. It also hoisted men and material in and out of the twenty-seven working chambers. A typical caisson or working chamber is shown in Fig. 3.

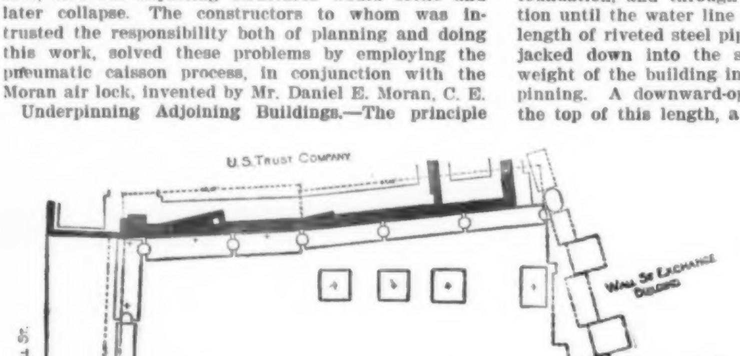


Fig. 2.

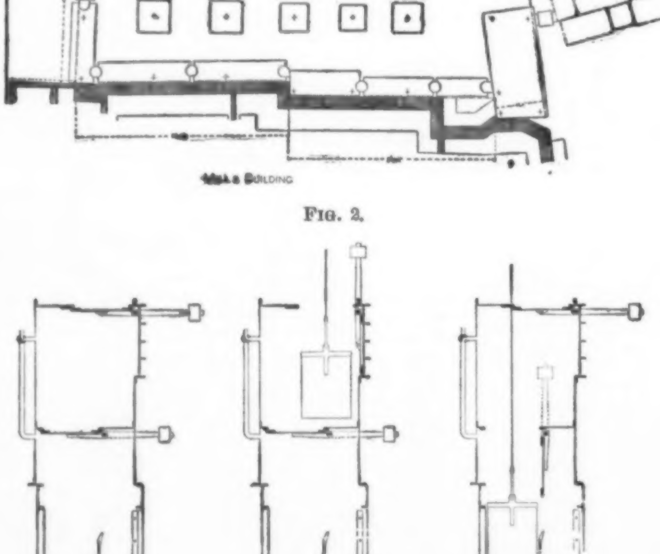


Fig. 4.

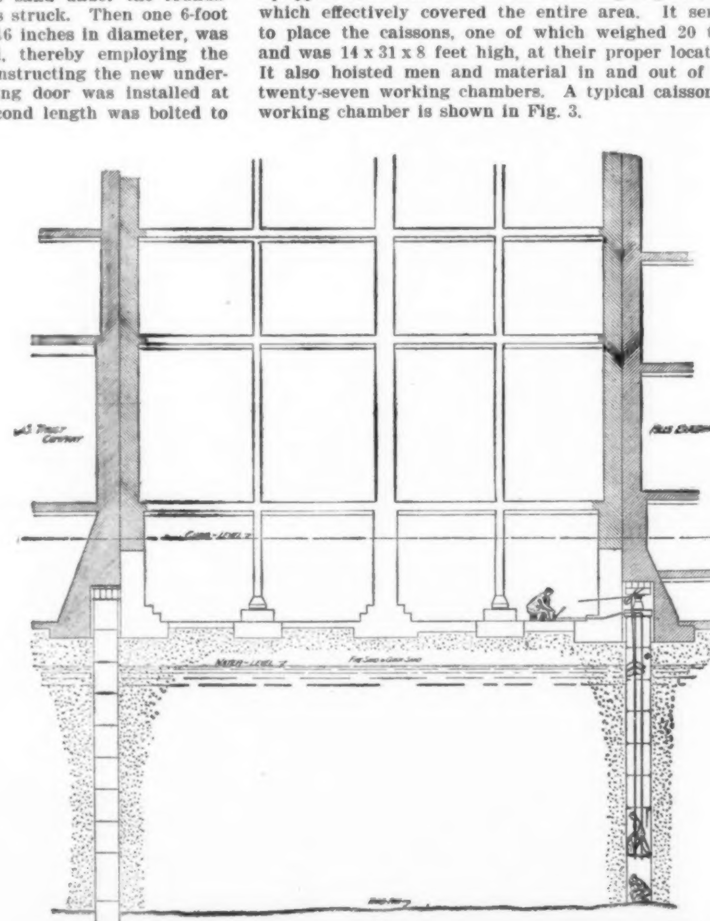


Fig. 5.

Fig. 6 also shows the air lock in place near the top of the picture. The man stooping down on the ground is the gage tender, who keeps the pressure steady for the convenience of the men in the working chamber, and the man at the air lock communicates signals between excavators and the engineers.

The Method.—Having a general knowledge of the difficulties of the apparatus to be used, and having finished the description of the underpinning, we shall take up the method employed in sinking the twenty-seven great concrete piers through this soft soil to bed rock without weakening the adjoining foundations. (See Fig. 6.)

After the wooden caisson proper had been located accurately the workmen with picks and shovels excavated inside the open-topped frame, which gradually sank of its own weight. After it had sunk to water

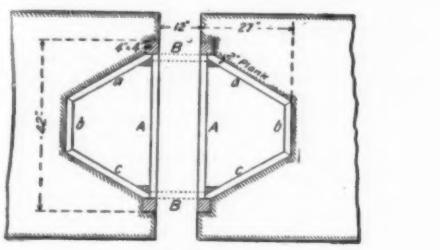


FIG. 7.

level, which was but 4 to 5 feet below the street, preparations were made to apply the compressed air as follows: The open top of the caisson was roofed temporarily over, and the first ten-foot section of the steel collapsible working shaft was joined to the upper part of the caisson as shown in Fig. 3. Section after section was added, and then an air lock, as shown in Fig. 6. A section of temporary wooden cofferdam was thereupon built and fitted to the outside of the caisson, so as to extend its sides upward several feet. This was to act as a false work for retaining the successive thin layers of concrete, which were dumped into the annular space inside the cofferdam, on the roof of the caisson, and surrounding the working shaft, as will be noticed in the right-hand side of section in Fig. 6. After the first ten feet of concrete had been laid and hardened, a second cofferdam was fitted in a higher position, and the concreting continued, the first cofferdam being later removed and used as the third. One gang of men and one mixer could move from cofferdam to cofferdam, applying about a 2-foot layer in each, so that by the time they returned to the first one, it was hardened enough to receive its next layer without distorting the sheeting. So, nearly the full height and full weight of the finished pier was used to force the caisson down to its final resting place on bed rock. As rapidly as the excavating could be done by the men inside, Portland cement was used on this job in a 1 to 2½ to 5 mixture.

Referring again to Fig. 3, it will be noticed that the bottom of the caisson sides is sharpened and is known as a cutting edge, since it follows the level of the excavation, pressed down by the great weight above. The contracting firm have prepared special 2-ton C. I. weights which can be piled on top of the concrete pier to sink it farther in case of the skin friction on the sides being too great for the pier to sink of its own weight.

During this process three eight-hour shifts of laborers were digging out material in the caisson under a pressure of from 18 to 24 pounds per square inch. This material was shoveled into buckets and hoisted up through the working shaft and the air lock out to

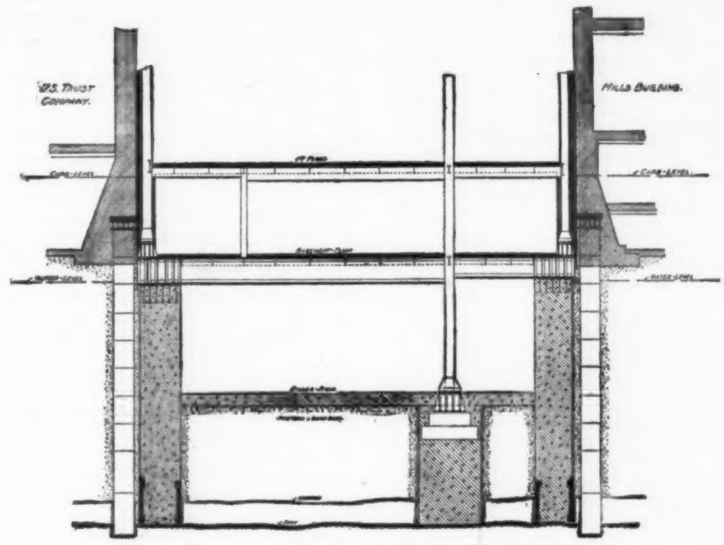


FIG. 9.

the open air, all in one continuous lift, as previously explained.

Filling in the Concrete Piers.—Upon reaching the rock, it was leveled off and under compressed air the concrete was lowered to the caisson and rammed in place. The entire caisson was filled to the top, the temporary roof removed, and as the men retreated up the tube they unbolted and removed the section of the collapsible tubing and hoisted it up for use in sinking another caisson. Gradually the entire space previously used as a passage for men and material in and out of the working chamber or caisson was filled with concrete, thus making the pier one solid monolith of concrete from bed rock to the column base. This is shown on the left side of Fig. 6.

Referring again to plan view, Fig. 2, it is seen that these piers are sunk end to end with only 12-inch spaces between, and that the chain of piers around the entire site is made perfect by welding or bonding between the ends of the piers. This keeps the water from the surrounding soil from entering either the basement or subbasement of the Trust Company of America Building. The method was as follows:

Fig. 7 shows the end faces of the two adjacent piers. The semi-octagonal groove shown in the faces was formed at the time the cofferdam was put around the top of the caisson. The wooden false work served as a core, displacing the concrete from its top to its bottom from each end face of each pier. As soon as two adjacent caissons were ready to be welded or bonded, the space bounded by *A B A B* was excavated. At the same time the laborers would tear off the boards *A A*, saw them into the shorter length *B B*, and nail them in position *B B* as shown in dotted lines. The spaces between the piers thus had become octagonal in shape and were carried down the few feet of the water level The planks *a b c a b c* were removed. A 4-foot length of steel cylinder 30 inches diameter was placed in the opening, and the space between it and the surrounding concrete and board, *B B*, was filled in with concrete and made air tight. An air lock was bolted to the top of this cylinder. The workmen excavated the material between *A* and *B*, tearing out all the lumber as they went down, and hoisted all the material to the surface except what was needed for completing the boards *B B* clear down to the top of the caisson. All this octagonal well was then filled to the top with concrete under pressure, and the bond was complete. When these connections between piers were completed on the north, east, and west borders of the building site, it was necessary only to make the bond with the foundation piers of the Wall Street Exchange Building on the south, in order fully to inclose the lot and prevent future flooding of the cellars, which reach to a depth of nearly 40 feet below the water level. It will be seen from Fig. 2 that this was done without the expense of sinking a separate line of caissons on that side.

Another advantage in this solid-wall type of bonded foundations construction is that those piers in the center of the lot can generally be sunk without the expense of the compressed-air method, for there is little danger of any water seeping in from the outside, and therefore of weakening the other buildings.

At this stage of the job the cellars can be safely dug, during which work the shoring of the neighboring

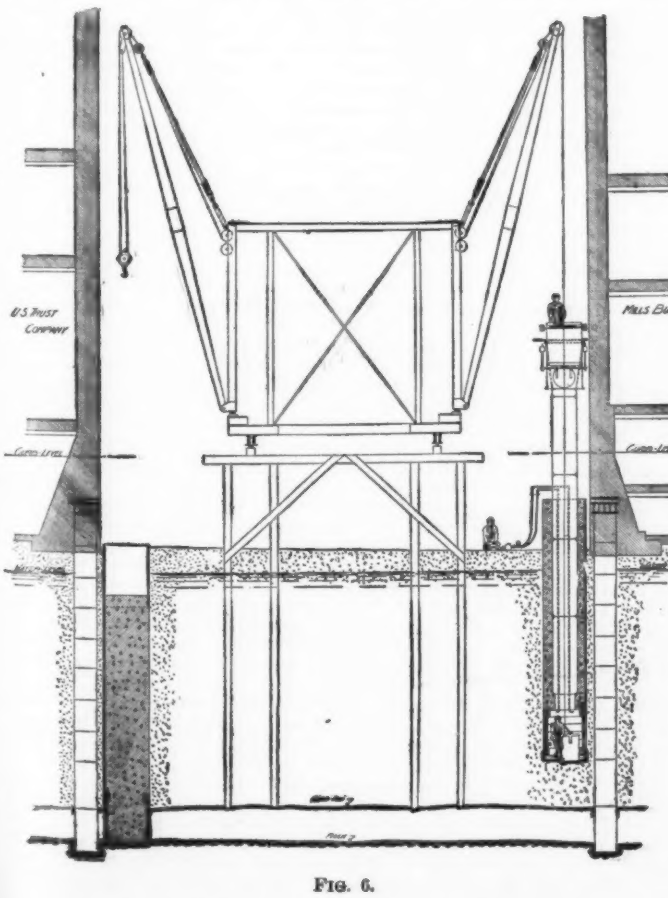


FIG. 6.

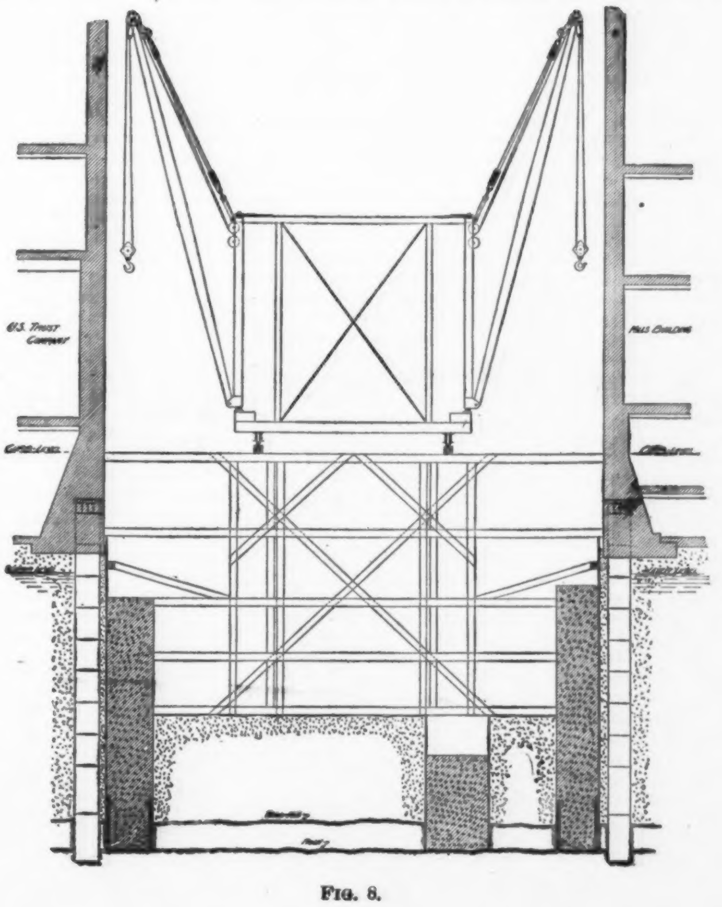


FIG. 8.

building walls is shown in Fig. 8. Fig. 9 illustrates the appearance when all the substructure is completed and the cellar made ready for installing engines and boiler.

THE EVOLUTION OF THE ELEPHANT.

By J. Percy Moore.

By no means the least important phase of the intellectual awakening that resulted from the publication of the "Origin of Species" was the impulse to trace the pedigrees and plot the genealogical trees of the various groups of animals recognized by systematic zoologists. This work was plunged into with such eager enthusiasm, that scientific caution was largely cast to the winds. The logical and certain method of determining the first course of evolution and the relationships of animals is to examine the actual records of their descent as preserved in the fossiliferous rocks. This method is, however, painfully slow, and in the hurry to arrive at results the much more obscure and misleading evidence of comparative embryology and anatomy was given a preponderating influence.

After a quarter of a century of great activity in the rearing of such schemes, a reaction set in, and a forest of withering phylogenetic trees has been tumbled into a confused mass of wreckage. As usual, this reaction was too extreme and the sound wood and the dead were alike discarded. The student of paleontology continued to delve into the secrets of the rocks and to read therein the history of the past. Recently a new and saner appreciation of the importance of genealogical studies among animals is becoming apparent. Among the vertebrates the lineage of many important groups has been worked out, sometimes, as among the horses and rhinoceroses, in much detail. Within a few years paleontology has for the first time cast some real light upon the origin of the vertebrates.

Naturally, the interest of paleontologists in phylogeny has been directed especially to the mammals, and because of the greater abundance and perfection of the remains success has been here most gratifying. The point of origin of most of the important orders of mammals from the common stem has now been satisfactorily determined and their evolution traced step by step to their modern representatives. Of course, the gaps in our knowledge are still many and great, but every year sees some of them closed up. The principal deficiencies in our knowledge of the beginning of the orders of mammals have concerned those which have sprung from the great continent of Africa, which until quite recently has remained an almost complete paleontological *terra incognita*.

Many paleontologists have looked upon the "Dark Continent" with longing, in the full assurance that in its unbroken strata were entombed the remains of the ancestors of several of the most isolated among the orders of mammals, notably the elephants, the sea-cows (*Sirenia*), and the conies (*Hyrax*). A prophetic surmise to this effect made by Prof. Osborn, of the American Museum of Natural History, had scarcely been penned before its truth was made known.

Few groups of mammals stand so utterly alone zoologically as do the elephants in the contemporaneous faunas. As is well known, there are but two living species, one inhabiting Africa, the other India. The former is distinguished by its smaller ears, smaller tusks and the much more numerous ridges on the grinding teeth. They are the bulkiest of land mammals and in numerous respects unlike any others now living. In many features, and especially in the structure of the legs and feet, they are reminiscent of ancient and generalized mammals, but in adaptation to feeding they have become much modified and specialized.

The particular conditions to which the elephants have become adapted and to meet which their structure provides are longevity, great size and the consumption of large quantities of coarse and innutritious food. The prime need is for a dentition of great efficiency and wearing qualities. The first is accomplished by the multiplication of the ridges of hard enamel and their support by a softer cement, the unequal wearing qualities of which two substances produce in usage a surface comparable to an old-fashioned millstone. The second is accomplished by an enormous increase in the height of these ridges and in the size of the teeth, so that a single tooth or parts of two completely fill the jaw at any one time. The others of the series, instead of being erupted nearly at the same time, as in most mammals, are held in reserve and move into place and functional activity from behind forward. As a result the elephant has a grinding apparatus which, even when subjected to the severe test of reducing woody twigs to a digestible pulp, fulfills the needs of the animal for the allotted century of its life. The remaining teeth, incisors and canines, have totally disappeared, except the second pair of upper incisors, which have developed into the enormous ivory columns or tusks which form so conspicuous a feature of the elephant's head and serve so well for fighting and uprooting trees. To give these great grinders and tusks ample support requires massive foundations in the jaws and skull. The greatly increased resulting weight of the skull necessitates a short and muscular neck; and for their adequate attachment the neck muscles require high vertebrate spines and a great occipital expanse of the skull, the latter of which has been gained by the very remarkable expedient of increasing the thickness of the cranial bones by means of extensive sinuses and chambers in their substance. It is an invariable rule among land mammals which secure their food and especially their drink on the level of the ground, that for obvious reasons a correlation exists between the length of the fore-limbs and the combined lengths of the neck and head. It must be obvious also that the excessive shortness of the elephant's neck must be compensated by the great elongation of the snout to produce the unique, prehensile trunk. The weight of the trunk again reacts upon the head and neck, both being further strengthened for its support. The reaching of a physiological balance among these various factors gives us one of the most remarkable animal forms that ever existed.

The principles of comparative anatomy and embryology and of evolution have enabled us long since to postulate in a general way the important steps by which the elephants have been produced. It has been clear that they arose from ancestors possessing a more normal dentition and proportions, and, indeed, the abundant remains of Pliocene and Miocene elephants and mastodons have carried us not a little way back on the actual trail of their lineage. Nevertheless all of these extinct animals were truly elephantine in nature. Paleontology helped us but little more than embryology in the quest, for, as is well known, the trunk develops gradually in fœtal life; the germs of the missing incisor and canine teeth are present; the elephant is born with thin skull bones and a longer facial region; and the milk dentition includes three grinding teeth, present simultaneously in each side of each jaw, the crowns of which approach much more nearly to the simpler tubercular character of the hog's molars.

Several previous attempts have been made to trace the ancestry of the elephants in both America and Europe, but they have been so manifestly artificial and speculative that little interest has been excited. It is little wonder that paleontologists have extended a ready welcome to the first real discoveries that have permitted the tracing of the elephant lineage beyond the confines of their own special groups close to the central stem of normally formed mammals provided with a complete dentition.

Far to the west of the Nile River in the Fayum region is the bed of the great fresh-water Lake Meris of the ancient Romans, now reduced to a series of salt ponds in the midst of a great sandy desert strewn with the fossilized remains of the forests that once covered the fair face of a country now a desolate waste. Here in the desert Dr. Andrews and his associates of the Geological Survey of Egypt have traced the pedigree of the elephant back through the Miocene and far into the Eocene Period.

Here the mightiest of warm-blooded land animals began in a simple, decidedly generalized animal of the size and somewhat the aspect of a large pig, named, in commemoration of the ancient lake, *Mericotherium*, and totally lacking the trunk, which is the badge and stamp, *par excellence*, of an elephant. So peculiar is this organ that Mr. Kipling has felt it necessary to explain its origin in one of his jungle stories. It will be remembered that at a long remote time, when elephants were trunkless, a discontented youngster wandered from home to see the world. In the course of his travels, becoming thirsty, he thrust his muzzle into a wayside pool, when that member was firmly seized in the vise-like grip of a crocodile. In the mutual struggle and tug that ensued the snout was stretched, and when the elephant finally broke away it had attained the proportions of a trunk, which, although acquired thus violently and mechanically, has been duly transmitted to all succeeding generations. The *Mericotherium* must be the veritable ventursome youngster described by Mr. Kipling, the truth of whose account is attested by the associated remains of numerous crocodiles, some one of which is no doubt the contributory mugger of the tale.

Mericotherium was a robust, somewhat pig-like animal with stocky limbs and short tail, with the brain case flattened and the facial region prolonged in quite the normal fashion, and totally unlike the conditions seen in modern elephants. The jaw length was ample to accommodate at one time a full set of teeth lacking only one or two of the number in the theoretically complete dentition of a primitive typical mammal. In the upper jaw the typical number of three incisors on each side is present, the second being somewhat enlarged to form a downwardly directed tusk, not differing greatly in size and form from those familiar in the jaws of many mammals, but prophetic of the great ivory weapons of true elephants. There is a small canine and following this, after a gap, six low-crowned, quadrituberculate molars, intermediate in structure between those of a hog and a mastodon. The lower jaw bears six similar molars and two incisors on each side. The skull bones are not thicker than ordinary and present none of that great development of sinuses characteristic of the elephants. That there could have been no trunk and at most only a prolonged upper lip or a mobile hog-like snout is evident from the structure of the nasal and maxillary bones. This animal undoubtedly cropped herbage and succulent plants in the ordinary way, the neck being sufficiently long to enable the mouth to reach the ground.

In strata of the same region, laid down at a somewhat later date in the Upper Eocene, at a time when the impulse toward the evolution of modern types of mammals was felt all over the world, Dr. Andrews found the remains of an animal marking a very distinct advance along the elephant line. To these, representing an animal as large as a horse, he gave the name of *Paleomastodon*. Compared with that of *Mericotherium*, the skull of *Paleomastodon* is distinctly more elevated and rounded in the cranial regions. The hinder part of the face is shortened so that the orbits are continuous with the temporal fossæ in which the jaw muscles lie. The anterior jaw region, or premaxillary bone, is decidedly enlarged to accommodate the sockets of the second pair of incisors which already possess many of the characteristics of the tusks of modern elephants. Correlatively with the disappearance of the first and third pairs of incisors and the canines, they have become quite prominent ivory sticks directed decidedly forward as well as downward. The corresponding part of the lower jaw is much prolonged forward and bears at the end a single pair of flattened, procumbent, and chisel-like incisors which were evidently effective in cropping herbage. In addition each jaw bears five pairs of grinding teeth, each with two or three enamel ridges across the crown. Undoubtedly this primitive father of all the elephants possessed a short but veritable trunk. It probably was not pendant and covered the base of the tusks only, but was sufficiently prehensile to be of great service in carrying to the mouth the succulent vegetation and roots which were grubbed up by means of the tusks.

The discovery of *Paleomastodon*, bridging, as it does, the gap between the elephants and the more typically-formed animals, fully establishes the place and manner of the origin of the former. From Africa they slowly spread through Europe and Asia to North America and finally to South America in several successive waves, evolving in each, and especially in Europe, peculiar types. Although our knowledge is still very fragmentary, there is no more fascinating problem in biology than the tracing of this leisurely migration, extending over ages of time, and accompanied by the even more leisurely evolution of these mighty beasts. We find the records of waves of advance and recession in both space and time. In evolution as in migration there were false starts and impassable obstacles. Some races proved unsuited to their environment and died out, leaving no descendants, just as some migrating bands succumbed to the rigors of climate, disease, or lack of food. Races and even types, like individuals, are mortal.

From the upper Eocene of Africa our knowledge of the elephants passes to the middle Miocene of Europe, where in the remains of *Tetrabelodon* (or *Mastodon*) *angustidens*, we become acquainted with an animal of distinctly elephantine aspect and proportions which marks the culmination of the tendency toward prolongation of the jaws forward and the enlargement of the lower incisors which was remarked as beginning in *Paleomastodon*. The most salient feature of this creature is this pair of lower tusks which resemble those of the upper jaw in form but are only about half as long. Like those of the lower jaw the upper tusks project straight forward but are about twice as long as the skull. A band of enamel which passes along their front face has misled some zoologists to suppose that the elephants arose from rodent-like gnawing animals. The structure of the facial bones and anterior part of the cranium, the occipital muscular attachments, and the comparatively short neck make it certain that *Tetrabelodon* was provided with a trunk of moderate length; but it is supposed that, instead of hanging pendent as in true elephants, it must have rested upon the produced upper tusks. What use the animal could have made of the lower tusks is entirely problematical, as for every purpose to which the elephant puts its tusks they would seem to be superfluous.

With the four-tusked elephants the main trunk of the genealogical tree forks. A shorter and decadent branch leads to and terminates in the remarkable Dinotheriums, which appeared in the middle Miocene of Europe and some of which migrated to India, where they continued to exist during the Pliocene period. In these animals it is the upper incisors that were reduced or lost and those of the lower jaw which developed into a pair of tusks. The prolonged symphysis of the lower jaw is bent abruptly downward, bearing the prominent tusks in a vertical position and giving to these animals a somewhat walrus-like aspect that has misled many non-zoological persons and even some zoologists. Notwithstanding this marked divergence the other characters possessed by the Dinotheriums, among which a trunk must be included, testify to their collateral relationship to the elephants. The second line is that of the mastodons, from some member of which the several races of true elephants sprang. They are characterized by the gradual loss of the lower tusks with a corresponding shortening of the jaw, especially at the symphysis, the increasing size and perfection of structure of the trunk, the dependent position of which became possible as the upper tusks diverged and the lower jaw became shorter. All of these characters are progressive, as are also the shorter neck, higher spines of the thoracic vertebræ and the shorter and more elevated cranium, with its extensive occipital surface and greatly increased cellular structure of the bones, all of which are correlated, as was pointed out previously, with the increased weight of the tusks and trunk. Although the molar teeth remain comparatively small and simple, being composed of broad, low, transverse ridges covered by a thick enamel layer and separated by open valleys, they do show a distinct advance toward a more complex structure in which the number of transverse ridges has increased from two to four, each of which is divided into two large conical tubercles, to which may be added a number of small mammillæ. The number of erupted teeth in each series is usually three and the succession is from behind forward, or only partly from below upward.

The mastodons were a prolific race which blossomed

profusely in Europe, emigrated into Asia and then over a neck of land, which reached across what is now Behring Sea during a large part of Cænozoic time, into North America. Reaching North America first in middle Miocene times and subsequently receiving accessions to their ranks through later migrations from the Old World, the mastodons spread over most of this continent and by means of the newly formed Isthmus of Panama crossed into South America, where their remains, found as far south as Buenos Aires, testify to the extent of their travels.

After producing a great variety of species differing much in the character of their teeth, as well as giving rise to the true elephants of the genus *Elephas*, which appears to have occurred in southern Asia, the mastodons became extinct in the Old World at the close of the Pliocene Period. In America, however, where they became less specialized, at least two of the species continued to live into post-glacial time. The fact that their very abundant remains, which often occur in great plenty in bogs and about ancient salt licks, are found in association with flint implements indicates that these animals were contemporaneous with man, who probably entered this continent from Asia by the same Behring Sea route. Just why these animals, some of which quite equaled or even exceeded the living elephants in size, should have become extinct is unexplained.

The true elephants, like the mastodons, had their center of development and dispersal in Eurasia, where they evolved into several stocks and many species and races which ranged in size from the pygmy elephants, no larger than a pony of the isle of Crete, to giants which, like the *E. meridionalis* of the Upper Pliocene of southern Europe, reached a height of 15 feet, or fully one-third more than the largest elephants exhibited in shows. During Pliocene and early Pleistocene times successive waves of migration extended from southern Asia over Europe, some of them reaching the British Islands; and it is believed that at least one may have swept over Greenland to North America. The emigration impulse and perhaps the pressure of over-population impelled other movements northward and eastward and resulted in at least two invasions of North America by true elephants which came by this route before Behring Isthmus gave way to Behring Strait. In Pliocene and Pleistocene times this narrow bridge of land was a much-traveled highway over which, there is abundant reason to believe, America received from Eurasia not only its first men but also its bison, musk ox, mountain sheep, and mountain goat, while it gave in return to the Old World its horses and camels. One stock of elephants (*Stegodon*), characterized by the relative simplicity of the teeth, sent its representatives from Asia back to the original home of the founder of the family in Africa and its present day descendants roam the wooded portions of that continent. Besides developing in greatest perfection the essential elephantine characters of trunk, tusks, etc., the members of the genus *Elephas* are especially distinguished by the character of their molar teeth. The low transverse ridges of the mastodon's grinders have become gradually converted into high prisms or thin plates of enamel arranged transversely to the length of the teeth and supported by the softer cement substance which fills the deep clefts into which the valleys have been converted. From the earliest members of the subgenus *Stegodon* to the highly evolved living and recently extinct species of *Euelephas* the number of these ridges has increased from six to upward of twenty. At the same time their height has increased and the cement filling has become more perfect. As a consequence the size and life of the teeth have been enormously enhanced. It is believed that the increased wearing capacity of this very efficient and powerful milling apparatus was correlated with an increasing longevity of its owners.

By far the most interesting of the true elephants and in many respects the primate of them all was the hairy mammoth (*Euelephas primigenius*) and its varieties. Although not so large as is popularly supposed, its height not exceeding that of the Indian elephant and being much inferior to some other extinct species, the northern mammoth possessed enormous recurved and slightly spiral tusks having a length in the males of 10 or 12 feet. The great molar teeth may attain a weight of 20 pounds each and are especially characterized by their unusual breadth and the very numerous, thin, and straight enamel plates, of which as many as twenty-seven have been counted on a large tooth. Unlike the elephants now living, which are hairy only before birth, the northern mammoth at least was covered with a dense reddish-brown wool and a matted coat of long blackish hair. Of this fact there can be no doubt, thanks to the combined testimony of rude sketches left by the contemporary cave-dwelling men of southern France and the well-preserved bodies which have been discovered in a half-mummied condition refrigerated in the frozen soil of the tundras of northern Siberia. Several such frozen bodies with hair and flesh complete, usually in an upright position just as they were entombed in the treacherous soil of bogs, have been unearthed. A perfect skeleton of one such, together with portions of the hair and flesh, is now preserved in the museum at St. Petersburg. It is even reported that dogs have fed on their flesh. The conditions under which these frozen mammoths are found has given wide credence in northern Russia and Siberia to the belief that these animals habitually live in subterranean burrows and that exposure at the surface to light and air is immediately fatal to them.

In pre-glacial times the mammoth ranged widely over the temperate and subarctic portions of the northern hemisphere, occupying most of Europe and Asia and a large part of North America, which it entered by the usual Behring gateway, and spread southeast along the margin of the great ice-sheet, with the wax and wane of which it appears to have moved south or north. Besides the hairy mammoth, at least two other species or well-marked geographical races inhabited North America, one of which, the *E. imperator* of Texas and other southern States, reached a much larger size and is supposed to have been hairless.

That the mammoth must have existed in great herds can scarcely be doubted. Their remains, and especially their great molar teeth, exist in enormous numbers, and their bones are said by Nordenskjold and other Arctic explorers to constitute a chief part of the soil of some of the river deltas of northern Siberia and the islands off the coast. In many places the collection of their ivory tusks for commercial purposes is an important industry. The true mammoth is a strictly Pleistocene animal. In America it did not survive the Glacial Epoch, and there is no proof that it was an associate of early man. Many animals, like the grizzly bear, musk-ox, and mountain goat, which accompanied it on the migration from Asia, remain with us. Why this animal, which was so well protected by its thick, wooly coat against the rigors of a northern climate and so well adapted to subsist on the coniferous scrub, should have succumbed to the glacial cold, as appears to have been the case, is difficult to understand. In Europe the mammoth survived longer, probably quite through the Glacial Epoch, and as has been already indicated, was well known to and hunted by early man. Then there too it succumbed to some force against which it was powerless; but just how and why we know not.

ELECTRICAL NOTES.

A standard of mutual inductance is being constructed by the National Physical Laboratory of England, the coils being wound on white marble and the whole arranged so as to facilitate accurate calculation from the dimensions. In order to insure good sensitivity in measuring, it is desirable to have the inductance sufficiently large, say 0.01 henry. To obtain this value a special design has been worked out. The primary winding consists of a pair of coils, each of one layer of bare wire wound in screw cuts on the same marble cylinder, their mean distance being about 0.7 of the diameter of the cylinder; the dimensions of these coils can be very accurately measured. The secondary circuit, which must have many turns, is a coil wound in a square sectional channel in a marble ring, and is so designed that its dimensions need not be very accurately known. It is placed symmetrically between and coäxially with the primary coils, and its mean diameter is about 1.5 times that of these coils. The proper ratio of diameters has been calculated, and, when this is used, the magnetic flux produced by a current in the primary coils through each single turn of the secondary is almost constant throughout a winding of 1 square centimeter section, and hence the mutual inductance can be found without highly accurate measurements of the channel-wound secondary (which would not be feasible). A method has been worked out for the experimental determination of this inductance when the construction is completed.

The Société Industrielle of Amiens, France, has organized a concourse for the present year relating to electrical or mechanical apparatus and inventions. Gold medals or cash awards are to be given. Among the leading awards are a gold medal for an electric generator of the mechanical, thermic or chemical type which shows the best conditions of efficiency and economy. A gold medal is also offered for an appreciable improvement in mechanical or other devices already proposed for avoiding accidents to workmen and bettering the hygienic conditions in factories, especially those which use mechanical motors. The same for a dynamometric brake which will be simple and cheap and allow of measuring the energy absorbed by a machine tool or similar device operated by belting or gears. A gold medal is proposed for a fuse block with a fusible metal which melts without giving a durable arc and for a well-determined current value, whose supports are non-conductors of heat and interchangeable, also easily repaired. An accumulator will receive a gold medal provided it answers the best conditions of efficiency as well as life. Such a battery must be actually in running order and must be a marked advance upon all such apparatus hitherto built. A gold medal will be awarded for an incandescent lamp which is a great improvement. It is to be made for all voltages up to 250 volts. With a consumption of 2.5 watts or lower per candle, it is to have 500 hours life at least, without drop in candle power. Five such lamps are to be presented of each of the types of 5, 10, and 16 candle power, standardized for 225 volts. Further information can be obtained from the president of the society, 29 rue de Noyon. Entries are to be made before the first of July.

Among the electric railroads which are using single-phase alternating current on the Continent may be mentioned the local road which connects Vienna with the town of Baden. This line connects with the city tramway system of Vienna on the one hand and on the other with the line from Baden to Vöslau. The interurban line in question is now using single-phase current with success, and the trains are run at a standard speed of 35 miles an hour. Motor cars are used which are of a long type, placed upon two bogies, with distance between bogie centers of 21 feet. The car carries forty-four passengers seated. Each of the two axles of a bogie carries a series monophase Siemens-Schuckert motor of 40 horse-power, with reduction gearing. These motors are of the ironclad type and have ten poles. In the present system the motors are grouped in pairs and each pair is connected in series invariably. To give the different speeds, the voltage at the terminals of the motor is varied by using a transformer which has a variable secondary coil. As the same cars are used on the direct current sections, the motors are designed to run also upon direct current, and here the speed is changed by coupling the two motor groups either in series or in parallel, giving the intermediate speeds by the use of resistance coils. The motorman has two separate controllers for this purpose, one of these being a series-parallel controller for running upon direct current, and the other a transformer controller which is used with the alternating current. Upon the roof of the car is mounted a single pantagraph trolley constructed of aluminium.

SCIENCE NOTES.

Certain industries yield a waste in great quantities composed of iron having a coating of copper alone or of copper covered in turn with nickel. The proportion of copper varies between 4.78 and 8.22 per cent, while the nickel may figure for 1.47 per cent. It is important to utilize this scrap, but the problem is a difficult one. According to the statements of K. Richter, it seems that for use in blast furnaces or Siemens-Martin steel furnaces this scrap contains too much copper, and again it is impossible to utilize it in apparatus for copper extraction by chlorides. Were it possible to find a simple and cheap process for separating the metals, a good part of the iron could be recovered, and the copper and nickel could be used again. Trials made with mechanical processes seem to have met with little success, using a sand-blast or other means. By heating in an oxidizing atmosphere and taking off the oxides produced (by means of grooved rolls) a better result is secured, but the separation is incomplete and the cost too high. Finally, attempts were made to separate the metals by electrolytic methods, and in this field relatively good results were met with. Here the scrap, perforated with a certain number of holes, is used as the anode, with lead cathodes. The separation of the metals is complete and simultaneous, and the copper comes down in powder upon the lead plates, thence falling to the bottom of the tank, while the nickel dissolves in the bath. The iron, freed from copper, can be used in the steel furnace. To carry this out on a large scale, the scrap must be cleaned first in iron drums full of quicklime, soda, and sand, then washed before going to the vat. The copper sediment is taken out at intervals and sent to the refining furnace. By evaporating the liquid we obtain the nickel.

After having established the fact that sea water contains fluorine in the proportion of 0.012 in 1,000 parts, P. Caries, of Paris, wished to find whether fluoride of calcium did not enter into the composition of mollusk shells. To this end oyster shells calcined and well powdered are boiled for two hours in water which is made alkaline by carbonate of potash. The filtered liquid is saturated with acetic acid in the presence of barium chloride, and with the residue he was able to engrave glass plates very easily. The shells must not be dissolved first in hydrochloric acid, as no results are obtained by this method, seeing that the hydrofluoric acid comes off together with the carbonic acid gas as it is set free. A better method is the following: Crushed shells are placed in five times their weight of water and heated in a water bath at about 50 deg. C. Acetic acid is added till they are dissolved, in the presence of a little barium chloride. It might appear that all the fluorine would pass into the insoluble part, but in fact most of it remains in the filtered liquid. The insoluble part can, however, be extracted by hydrochloric acid. Analysis to find the amount of fluorine contained in different kinds of shells shows that for fresh Arcachon oyster shells there is 0.012 per 100 parts, which is ten times the amount contained in sea water. Mussel shells give the same proportion. Fossil oyster shells obtained in France give 0.015 per cent. It thus appears that oysters and mussels assimilate the earthy fluorides from the sea in order to consolidate their shells in the same way as the vertebræ for the internal skeleton.

In a paper read before the Académie des Sciences, M. Hanriot describes the action of a new poisonous substance, *tephrosine*, and shows that fish are especially affected by it, even in the most minute quantities. This substance shows some remarkable properties in this respect, and it is one of the strongest poisons known. The tephrosine which is extracted from the *Tephrosia Vogelii* according to the author's method, is a crystalline body of well-defined character. It is almost entirely insoluble in water, but dissolves in alcohol and glycerine. He dissolves 0.01 part of tephrosine in 10 parts alcohol and then dilutes with 50 parts water. This solution contains 2-10,000ths of the active substance. A certain quantity is poured into a gallon of water so as to obtain the right degree of strength. When a fish is placed in such a solution it becomes greatly excited and often jumps out of the vessel, then it becomes quiet, its fins are paralyzed and discolored. The fish rolls in the liquid, then overturns and floats on the surface, finally dying. A solution of about 1-50,000,000th of the substance is mortal, but the fish, however, does not actually absorb all of the poison, as when a second fish is placed in the vessel it succumbs as quickly as the first, and so on for a great

number. The actual amount absorbed is exceedingly small. It seems therefore that the new substance must be ranked among the strongest poisons or even the strongest known, outside of certain venoms and toxines. The perch is one of the fish which is most affected by it, then comes the eel, and the last in the list is the lamprey, which resists forty-eight hours to a solution of 1-1,000,000th. Animals are much less affected by it, rabbits can even eat the leaves of the plant, and dogs can stand a dose of 15 grains of it. Frogs may be kept in a 1-200,000th solution in which fish would die instantly. The above poison seems thus to have a specific action upon fish.

ENGINEERING NOTES.

As feed water furnished to steam boilers must be heated from a normal temperature to that of the steam before evaporation can commence, this is generally at the expense of the fuel, which should better be utilized in making steam. All of this heat, therefore, which can be imparted to the feed water is just so much saved, not only in the cost of the fuel, but in the capacity of the boiler, and it is essential that this be done by heat, which would otherwise be wasted, as the heat imparted to the feed water by injectors and live steam heaters comes direct from the fuel and represents no saving.

It is difficult to obtain correct figures on the total savings that can be effected in the production of iron by the application of gas power, but from 50 cents to $1 per ton of pig iron made has been recorded in various continental works. In central electric stations which are located where no energy is available from near-by iron smelting plants or coal mines, the gas producer takes the place of the blast furnace and coke oven as the potential source of energy. Especially is the production of electric power at reasonable rates of importance for very large cities where the price of real estate in the centers of districts is high, and for isolated communities, country houses, and farms which are located outside the commercial radius of metropolitan or other central stations. The distribution of town gas for individual power purposes, while not so much restricted to central location within the city cannot, without loss, be extended over wide territories. Moreover, at the present price of illuminating gas, it cannot compete in the field of power production with the independent suction gas plant even if the latter use such high grade fuels as anthracite and coke.

A new dredge of some size has been built by the Lübeck Machine Company, and is now in service in Germany. It is electrically operated, using apparatus of the Siemens-Schuckert type. The dredge is designed to lift 6,000 cubic feet of earth per hour at a maximum depth of twenty-seven feet, advancing eight miles an hour. Its total length is about 145 feet and width 28 feet, with a 6.5-foot draft at full load. In the middle of the hull are placed the boilers and machine room. As to the boiler plant, it comprises two tubular boilers working at ten atmospheres, while there are two steam engines of 175 horse-power which operate screws. A third engine of 220 horse-power is coupled to a dynamo on each side. For the lighting, there is a separate engine of 25 horse-power which drives a special dynamo. The four engines work with a common set of condensers. Each of the dredge buckets carries eight cubic feet of earth. The raising and lowering of the dredge system as a whole is carried out by a 12-horse-power motor, while the drum working the chain of the buckets is operated by a 100-horse-power motor, using a hydraulic coupling. The latter is placed between the motor and the drum, and is designed to limit the couple given by the motor below a certain fixed value. To this end it affords a slip when the resistance encountered by the bucket on the river bed is too high. The fore capstan and the side capstans are geared to motors of 14 and 12 horse-power. All the apparatus of the dredge is operated from a central tourelll.

According to recent reports, it appears that there is a project on foot for a second tunnel through Mt. Blanc. The matter has been taken up on the Italian side, and a technical commission which was appointed by the municipality of Turin presented a report upon the subject not long ago, after examining the different projects for a new railroad through the Alps which had been presented. The Italian commission is in favor of a line of railroad running from Aoste to Chamonix, passing through a tunnel under Mt. Blanc. Starting from Aoste, lying at an altitude of 1,880 feet above sea level, the new line would mount along the Doire River to Pré-St. Didier (3,440 feet altitude) and would pass through Mt. Blanc in a tunnel some 11 miles in length. Leaving the tunnel, the railroad is to end at Chamonix or at Houches, a small village about 4 miles from the mouth. The total length of the proposed line will be about 35 miles. The culminating point of the tunnel will lie at an altitude of 3,460 feet. As the railroad is to be a trunk line of heavy traffic, the maximum grade on the Italian side will not be over 12.50 per 1,000, and will thus keep about the same grade as the Turin-Aoste road, of which it is to be the extension. From Chamonix to Geneva an already-existing road will be utilized, by Fayet, St Gervais, Sallanches, Cluses, and Annemasse, which, however, is to be entirely overhauled and improved. In this way Chamonix will be only 120 miles from Turin, and Geneva at 165 miles. The commission brings out the great value which such a line will have for the city of Turin, and it will compete with the new Loetschberg railroad which is now in construction.

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